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THE OVERHEAD PROJECTOR IN THE PHYSICS LECTURE.

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SOME SUCCESSFUL APPLICATIONS OF OVERHEAD PROJECTORS IN THE PHYSICS LECTURE HALL AT RENSSELAER POLYTECHNIC INSTITUTE ARE DESCRIBED--(1) PRODUCTION AND USE OF TRANSPARENCIES, (2) THE OVERHEAD PROJECTOR IN THE DEMONSTRATION LECTURE, (3) BREAD-BOARD FOR ELECTRICAL CONNECTIONS, AND (4) AN X-Y PLOTTER FOR THE OVERHEAD PROJECTOR. (MS)

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By

Walter Eppenstein

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RENSSELAER POLYTECHNIC INSTITUTE TROY, NEW YORK

THE OVERHEAD PROJECTOR IN THE PHYSICS LECTURE

Walter Eppenstein

Department of Physics

Under Grants from the

Course Content Improvement Section

of the

NATIONAL SCIENCE FOUNDATION

Rensselaer Polytechnic Institute

Troy, New York

December 1961

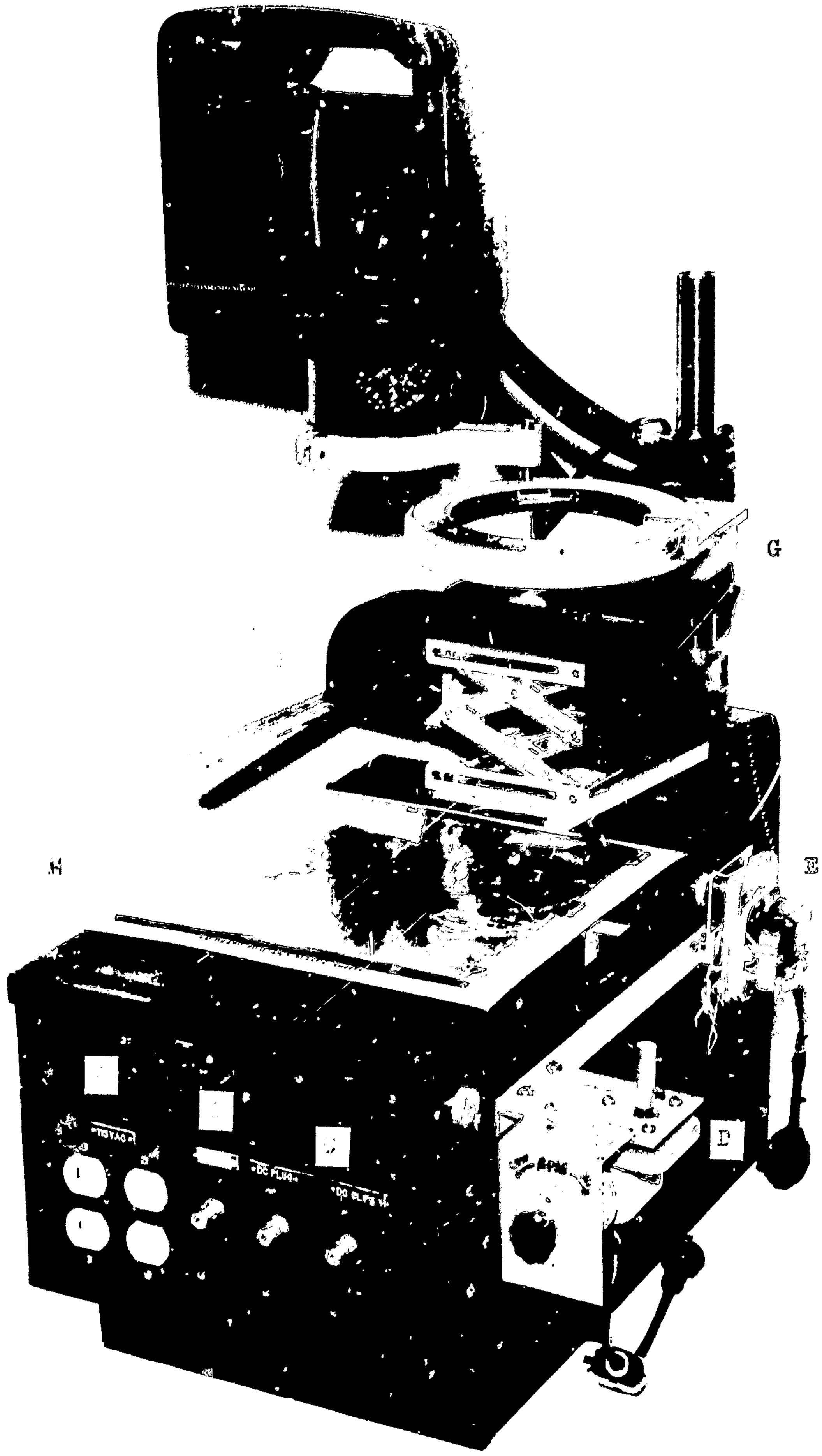


Fig. 1. A Vu-Graph overhead projector with the following accessories:

A - supplementary 115 volt A C outlets
B - 6 volt A C outlet
C - 6 volt or 110 volt D C outlets
D - variable speed motor
E - constant speed motor driving acetate roll
F - frame for mounting bread-boards for electrical connections
G - polaroid spinner for use with technamated slides
H - mounted colored overlay

PREFACE

With the recent interest in overhead projectors for teaching at all levels, it became evident that this very efficient optical system is more than a replacement for the blackboard. Wherever science lectures are given to large groups of students, working models as well as actual demonstrations can be projected effectively.

In this report, some examples of the applications of overhead projectors are presented. It is our hope that our successful use of overhead projectors in the teaching of physics will inspire others to develop their own accessories and demonstrations. We expect that an exchange of ideas will take place, with the Visual Aids Committee of the American Association of Physics Teachers acting as a clearance house, and resulting in a number of notes or articles in the American Journal of Physics and the new Demonstration Source Book now in preparation. We would welcome any suggestions along these lines or comments on the report itself.

The work outlined in the following pages, and indeed this report, would not have been possible without the financial assistance of the National Science Foundation.

The author also wishes to thank all those who have contributed to this project. Mr. Richard Heavers and Mr. Stuart N. Crouse have helped to design various models. Professor William L. Millard and Mr. R. K. LeVan of the Office of Institutional Research at Rensselaer Polytechnic Institute have produced most of the transparencies and have also contributed to the writing of this report. The many suggestions made by Rensselaer Polytechnic Institute staff and students as well as visitors were highly appreciated.

Troy, New York
December 1961

Walter Eppenstein

CONTENTS

INTRODUCTION

In recent years the overhead projector has found its way into schools and colleges. Its many advantages over conventional black boards are discussed by the leading manufacturers in their literature and examples are given in numerous publications some of which are listed in appendix A. In this report we shall assume that an instructor has an overhead projector at his disposal and is familiar with the operation of this device and its accessories. Information on projection distances, image size and the positioning of the screen to minimize the keystone effect is usually given by the manufacturer.

In our use of overhead projectors, we have restricted ourselves to the 10" by 10" stage which seems to be common to most projectors put on the market in recent years. The projection lamps used nowadays are usually of the 1000 watt type, although a few older models use 500 watt lamps. A few typical projectors currently available are shown in appendix B, together with their specifications and present costs.

It is not the purpose of this report to give a complete summary of applications of the overhead projector in the physics lecture, but to give examples of some of the specific ways in which it can be used. It is then left up to the ingenuity of the lecturer to invent his own accessories designed to fit his particular needs. These needs depend on many factors, such as the level of the course, the course material covered, the number of students, the size of the lecture room and the availability of materials as well as of shop facilities. It is hoped that the examples chosen will stimulate the physics lecturer sufficiently so that he will add his own ideas to those presented.

All accessories described have been designed specifically for the physics lectures presented to the Freshman and Sophomores at Rensselaer Polytechnic Institute. Our lecture hall holds 320 students and has, on occasions, been completely filled. In general we lecture to 260 to 300 students. Although the lecture hall has been designed many years ago, it is well suited for overhead projection because of the considerable distance from the first row to the demonstration table. The front screen is sufficiently high to avoid any interference from the projector, the lecturer or the demonstration equipment. Large demonstration pieces on the lecture table make the use of the overhead projector almost mandatory, because the blackboard is easily obscured. The spot and blackboard lights are usually turned off when the projector is in use; they are turned on for other demonstrations. The level of illumination in our lecture hall is continuously variable and is - for best visibility - set somewhat below the maximum level. Every effort is made to have as much light as possible at all seats and still get a clear image on the screen.

At this time it may be pointed out that the use of the overhead projector

teaching sections of twenty students because of the possibilities of preparing materials ahead of time and demonstrating phenomena difficult to show by any other means.

For the purpose of this report, the accessories devised for use with the overhead projector in physics lectures have been divided into four groups: Transparencies, models and demonstrations, breadboard for electrical experiments and the x-y plotter. Each of these will be discussed separately.

PART I

PRODUCTION AND USE OF TRANSPARENCIES

1. Replacing the Blackboard

The usefulness of the overhead projector in replacing the blackboard is generally discussed by the manufacturers and will not be dealt with at great length in this report. The lecturer faces his class, he is able to watch the students and thereby judge their reaction to his presentation, he stays at the same place throughout his lecture, and he does not have to erase part of his lecture. In a demonstration lecture there is also the possibility that large pieces of equipment on the lecture table may obscure the blackboard, at least for some students. A screen at the center of the room is high enough to give a clear view to everyone in the lecture hall.

The main advantage in lecturing by use of the overhead projector is, of course, the possibility of preparing material ahead of time. This preparation may be done by the lecturer just prior to his lecture, the night before, or by an artist in a professional studio, depending on the time and funds available.

Once a transparency has been prepared, it is stored for future use and is always available. When a file of overlays has been built up, the task of preparing and giving a lecture will be very much simplified. Besides their use for regular classes, such a collection of transparencies has proved very helpful when preparing programs for various groups.

2. Design of Transparencies

An overhead transparency consists of a number of visual elements which have been carefully related to one another so as to form a unified composite visualization of an idea, event, object, and the like.

Transparencies which communicate effectively result from the knowledgeable application of the principles and elements of design.

The principles of repetition, balance, emphasis, unity, and contrast in design are the guides employed by the artist when creating a plan for arranging the various parts of the transparency.

Space, line, color, size, shape, and texture are the tools with which the artist works to make the design of the transparency as effective as possible.

Good design is a significant factor in determining the communicative power of any overhead transparency. It is important that the content authority,

as well as the artist who prepares the artwork, develop an understanding and an appreciation for the role played by these design characteristics in the preparation of effective instructional materials.

Actual production of the final transparency begins with the design and layout of roughs. These are simple quick sketches of each visual to be prepared. The rough is designed so to present the essential idea of the content and structure of the final visual.

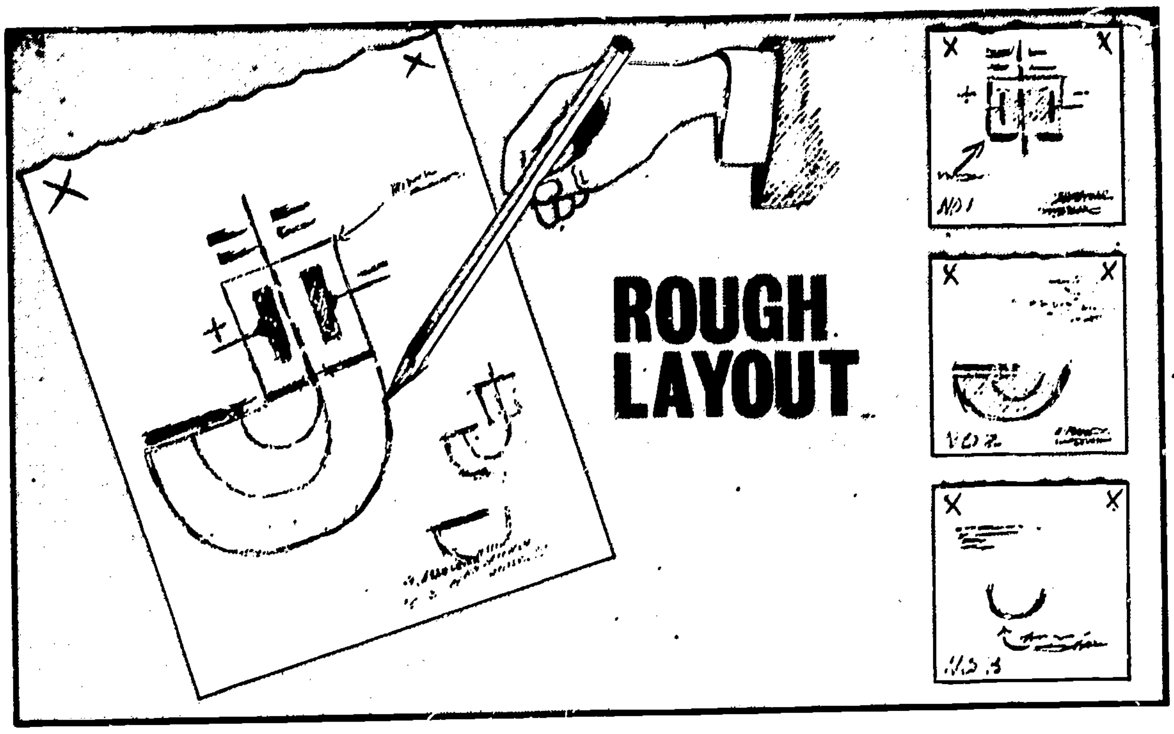


Fig. 2. Rough layout

Roughs show each significant step in the visual design of the final transparencies. Roughs may be prepared initially by the content authority or the artist. Usually if an artist is assigned to the project it is his responsibility to prepare the roughs.

Roughs serve as the vehicle for arriving at a decision as to the correct visual design and layout of content. Roughs may go through a series of revisions before finally being approved. The artist should submit all roughs for approval before preparing comprehensive layouts.

A comprehensive layout is a detailed drawing of the final visual. It is not the final piece of artwork, although it contains all of the elements of the final transparency.

If the comprehensive layout is to result in a transparency the artwork is normally prepared exact size. The artist usually makes notations as to colors, style of type, and the like which will be used in the final product. If the finished artwork is to consist of a series of overlays then the comprehensive layout should show the exact content for each as separate drawings. These separate drawings can be registered in sequence, one over another, and viewed in a composite form much as they will function in the final overlay transparency.

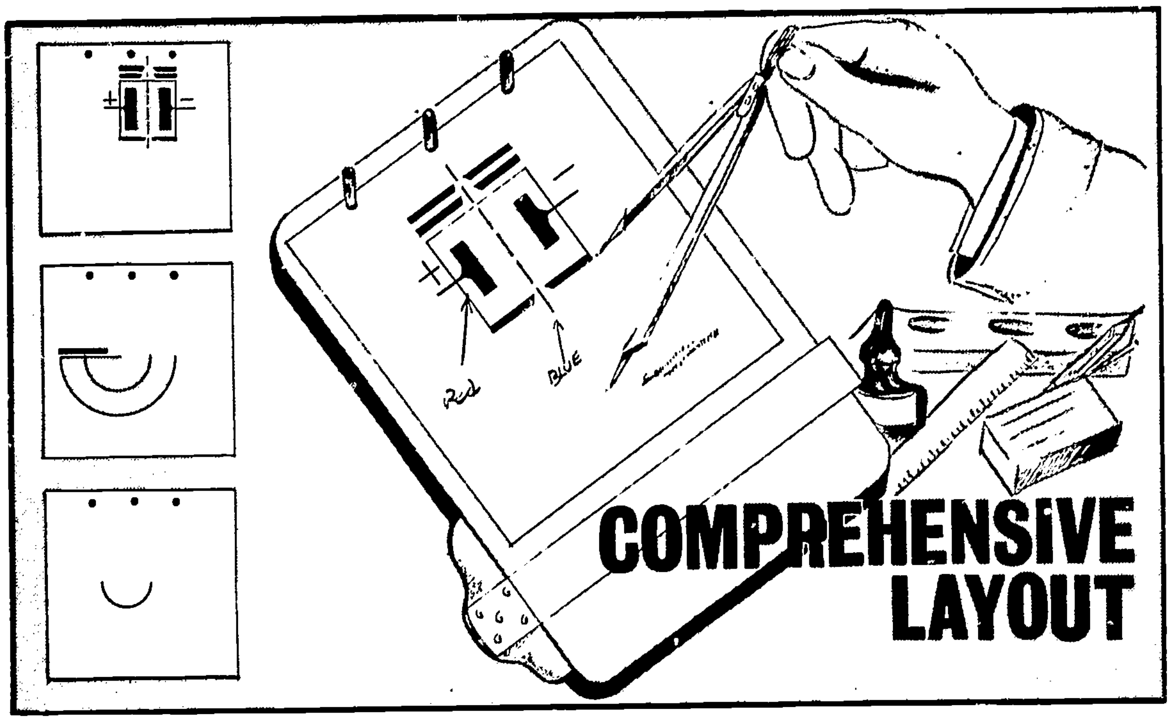


Fig. 3 Comprehensive layout

A pin registration system is a desirable tool for use in preparing comprehensive layouts and finished artwork. A registration system of this type is important where accurately registered multiple overlays are required. Registration pins, prepunched tracing papers, and printing materials, and registration punches are readily available for this purpose.[1]

At this point the comprehensive layout should be carefully evaluated in terms of the original educational objective for which it was designed. Details of the visual elements and text should be checked for errors. Any required revisions should be made before releasing it to the artist for preparation of the finished artwork.

The finished artwork is accomplished through the artists skillful application of art materials to fulfill the elements of design contained in the comprehensive layout. The artist of today has in addition to his own skill in creating and producing visual materials, available a wide assortment of prepared art materials. These include sheets of letters, numbers, designs, textures, patterns, figures, shading materials, and other symbols. These materials can be obtained in a wide variety of sizes and colors, either opaque, translucent, or transparent. Since they contain their own adhesive they are simply cut out and pasted up on the layout surface.

In addition, a wide variety of opaque, translucent, and transparent tapes are available in varying widths, colors, and designs, Plain black and white or colored tapes are used for drawing straight lines or circles. Tapes are

1 Technifax Corporation, Holyoke, Massachusetts or
Eastman Kodak, Rochester, New York

also available which contain numbers, letters, symbols and the like.

Finished artwork may be prepared either for direct "as is" use on the overhead projector or for reproduction purposes in making one or more copies on transparent materials.

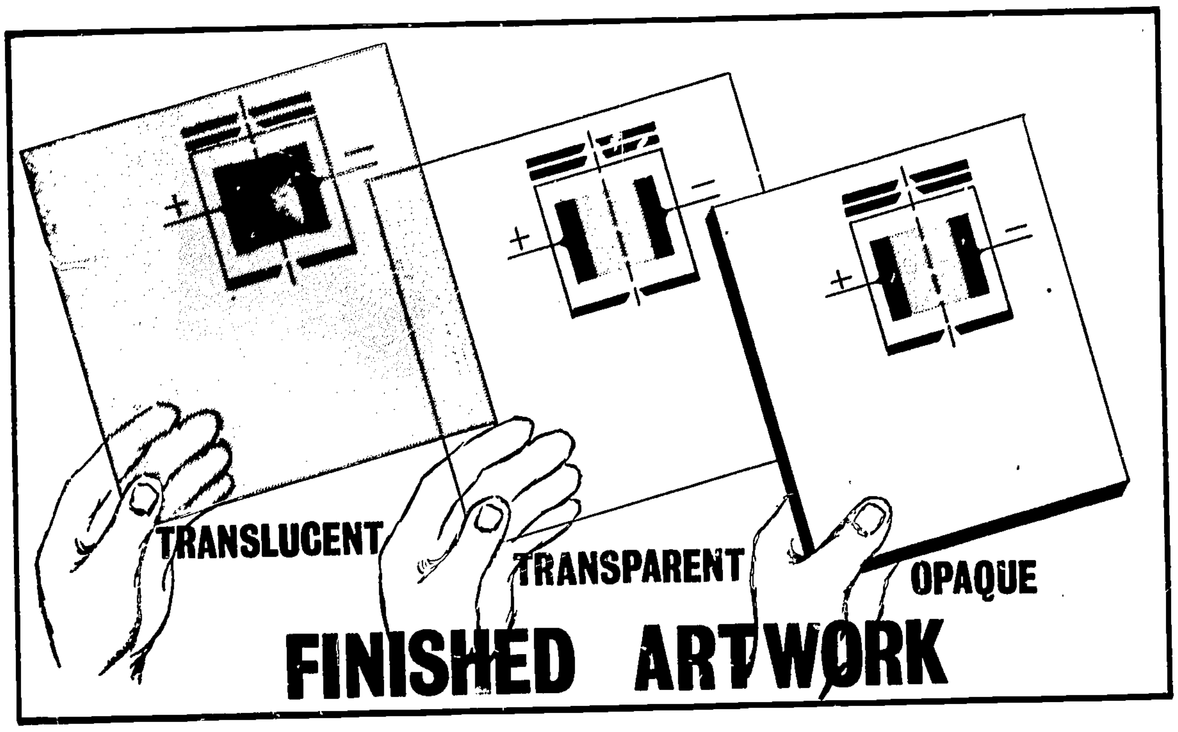


Fig. 4. Finished Artwork

Artwork for direct use as a transparency for overhead projection must be prepared on clear transparent acetate or plastic materials using transparent inks, paints, tapes, screens, letters, and the like. Although common types of plastic or acetate materials are acceptable when the visuals are prepared using gummed transparent materials, they are not recommended for inking or printing. Specially treated acetate sheeting is available where acetate type inks or paints are required in preparing the visual.

Finished artwork to be used as a master visual from which reproduction transparency copies are produced may be prepared using a variety of materials. The process used in preparing the artwork is usually selected in terms of the efficiency of preparation, art materials required, and especially the printing process to be employed.

Finished Artwork for Contact Printing. Finished artwork to be contact printed on high contrast photographic film, diazo foils, or thermal process materials may be prepared as follows:

a. Translucent tracing or drafting papers are the most economical preparation surface materials and accept the widest range of art preparation materials. Printing time is longer than for clear transparent materials. Transluscent plastic or acetate may be used instead of drafting papers. Cost is increased and some types of art preparation materials do not adhere well to the surface unless it is specially treated.

b. Transparent clear acetate or plastic artwork preparation surface materials offer increased printing speed. The working surface does not accept as wide a range of art preparation materials as paper unless it is specially treated. Cost is substantially greater than for paper materials.

c. Opaque materials as artwork preparation surfaces may be used but require a reflex printing process. For reasons of quality and complexity of the reproduction process these opaque preparation surfaces are not generally used in preparing artwork for contact printing.

d. Contact printing requires that opaque materials be used in laying out the original artwork on the preparation surface material. This is so because the printing process utilizes the principle of blocking out the exposing light source where an image is to be formed.

Even when color transparencies are to be prepared the original artwork needs only to be prepared with opaque materials. The element of color is contributed only by the printing material used. Thus all that is required to obtain any appropriate colored transparency from a single piece of artwork is to select the proper printing material.

Finished Artwork for Photographic Printing. Finished artwork to be reproduced by photographic camera copying techniques may be prepared by any of the techniques previously described. The artwork is simply photographed by the camera and normal photographic transparency production procedures are used in preparing the finished visual. In addition, artwork may be prepared on surfaces of inexpensive opaque materials as illustration board, plyboard and the like. Where rigidity of the preparation surface is important opaque materials have the advantage over printable translucent artwork preparation surfaces. The camera copying process allows the preparation of certain kinds of artwork not possible using contact printing methods.

Prepared black and white artwork may be combined with existing artwork, graphic materials, photographs, printed matter, and the like and copied in one step by the camera to produce a composite black and white transparency. Artwork may also be combined with three-dimensional materials by multiple exposure techniques.

Color may be added to the black and white photographic transparency by dye processes. Full color original artwork may be prepared and reproduced as a full color transparency using the camera and color reversal film. Combinations of artwork can be utilized as in black and white reproduction.

3. Printing and Developing Transparencies

The four main types of reproduction processes available for the preparation of overhead transparencies are: 1. photographic; 2. diazo; 3. thermal and 4. electrostatographic. A very brief discussion of each will be presented and for further details the reader is referred to the literature published by the manufacturers of the materials.

Photographic process. Photography offers great flexibility in the preparation of overhead transparencies. Artwork and objects can be enlarged, reduced, printed and rephotographed in combination with other materials to achieve a variety of unusual effects. Several photographic processes are available:

a. Reflex copying. Opaque materials, such as illustrations, photographs or objects which do not require reduction or enlarging, can be made into transparencies using reflex copying techniques. Reflex copying may be carried out in subdued light, using special low speed film and standard photographic chemicals and techniques. Office type photocopying machines may also be used to prepare transparencies in a one-step process.

b. Camera copying and projection printing. Standard photographic cameras of large format such as 4 x 5, 5 x 7 or 8 x 10, can be used to produce transparencies. Artwork is copied and the photographic negative is used directly, reprinted exact size, or enlarged to the desired size through projection techniques.

c. Contact printing. Photographic negatives, opaque materials, and objects can be used to produce transparencies by placing them directly on the film material and exposing in a suitable printing frame. Processing is done by normal photographic techniques.

Diazo process. Diazo-sensitized films[1] provide a convenient and inexpensive way of preparing a wide variety of black and white and color transparencies by contact printing methods. Diazo films are available in at least ten colors and secondary colors can be produced by superposing one color over another. This makes it possible to prepare multi-color transparencies for overhead projection usually at a lower cost per visual than by full color photography.

Diazo printing is a direct reproduction process where a positive original produces a positive copy and a negative original produces a negative copy.

1 Diazo materials are available from the Charles Bruning Company, Mount Prospect, Illinois, the Technifax Corporation, Holyoke, Massachusetts and OZALID, Johnson City, New York.

A print is made by exposing the diazo-sensitized material to ultraviolet light through the original artwork. The exposed diazo film is processed in an aqua-ammonia vapor where the diazo combines with a coupler to form a dye-image. This diazo printing process may be carried out in any normally lighted room if the film is not subjected to direct sunlight or prolonged exposure to fluorescent lights.

Printing and developing equipment may range from the very simple to the rather expensive apparatus. For the production of transparencies in small quantities an ordinary "sun lamp" has been used as the ultraviolet light source, a photographic printing frame to hold the film and artwork and a "pickle jar" with a sponge and some ammonia as the developer. A variety of portable printers are available for faster production of transparencies.[1] Use can also be made of the more expensive ammonia developing diazotype machines found in printing establishments and graphic arts shops.

Thermal process. Projection transparencies from a variety of original materials can be prepared in seconds using office type thermal process machines.[2] Both positive and negative copies can be prepared from the same original. Information not wanted on the transparency can be masked out before printing. By double printing separate visual materials may be combined in a single transparency.

Originals may be opaque or translucent, printed on one or both sides, but they must contain a carbon base or the equivalent, if they are to be reproduced by the thermal process.

Office copying machines generally produce 8 1/2 by 11 inch transparencies, while the overhead projector stage is 10 by 10 inches. Although color film material is available, it requires a liquid processing solution and had not yet reached the development where it might be considered practical.

Electrostatographic process. The electrostatographic process, such as Xerography, is an electrostatic process for producing copies from any type of visual material.

Original material, printed artwork, drawings and the like, is reproduced exactly to size on office type copying machines. Presently the equipment using this process is designed to make paper copies and transparent material are not generally available. It may be anticipated, however, that such

1 Among the companies selling printing machines for the diazo process are: Charles Beseler, Technifax and Ozalid.

2 The Thermo-Fax copying machine, manufactured by the Minnesota Mining and Manufacturing Company, has been used to obtain transparencies in four seconds.

transparencies will be developed in the near future.

Comparison of printing processes. In the production of the transparencies listed in appendix C and many others produced during recent years, the diazo process was used almost exclusively. This process proved to be the cheapest as well as the simplest to use especially in connection with color overlays in which carefully prepared art work is desirable.

For the case in which color is not important, the thermal process is certainly the most convenient one. There the lecturer can produce a transparency on a Thermo-Fax copying machine from any printed or written material only minutes before his class, making this type of process invaluable for last minute black and white overlays.

In a few cases photographic processes were used because of special requirements, such as enlarging or reducing originals.

Mounting. Most manufacturers selling printing materials have frames and other mounting accessories available. For easier handling as well as for proper storage, the mounting of all transparencies is very important. When using overlays it is most important to register or center the slides correctly so that the result becomes meaningful. Numerous devices are on sale to facilitate this operation.[1]

4. Use of Single Transparencies

Single transparencies, produced by any one of the various methods mentioned above, replace the regular slide as well as the blackboard. The lecturer's ability to add to or complete such a transparency makes it much more useful than the common small slide. A bubble chamber photograph, for instance, may be projected first. The lecturer can then show the tracks he is interested in and write out the nuclear reactions in appropriate places. Any marks made on the transparency with a grease pencil or a colored marker can easily be removed.

It is quite obvious that the single transparency can also be used to prepare lectures or problems ahead of time. It gives the lecturer a chance to write out his lecture at his desk rather than on the blackboard. Quizzes may be projected with solutions shown after the quiz.

In using the overhead projector for such purposes the lecturer should avoid the presentation of too much material all at once. It is never

1 Technifax Corporation, Holyoke, Mass. and Ozalid, Johnson City, N. Y.

desirable to have a lengthy derivation or a complicated problem suddenly appear on the screen. This does not always give the student a chance to follow the exposition in an orderly manner, nor is he able to take notes. It is better to cover such a transparency with a sheet of paper which is removed slowly, line by line, at a pace not too fast for students to follow.

It is very important to pay close attention to the size of the writing on the transparencies, as well as the space left for figures. How large a symbol to use in order to be clearly readable from the last row of the lecture hall depends, of course, on the size of the classroom, as well as on the size of the image or screen. Every lecturer must try various letter and figure sizes in each room before making any transparencies. It was found, for instance, that typed materials were not suitable even for medium sized rooms. Besides the size of letters and figures, the line width and the color used are important factors in assuring maximum visibility.

A set of coordinate system transparencies is commercially available[1] and may prove useful in physics lectures. The set of five single 10" x 10" slides includes rectangular, polar, 2-cycle semilogarithmic, 2 x 2 cycle logarithmic and 3 dimensional rectangular coordinates.

5. Use of Colored Overlays

While the single transparency is a substitute for slides or blackboards, the colored overlay uses techniques not possible by any other means. A complicated picture or diagram may be built up in front of the students by using up to six or eight transparencies of different colors. With a basic transparency mounted in a frame, colored overlays can be flipped on or taken off from all four sides. In Fig. 5 a crystal model is shown as an example. By means of overlays one atomic plane after the other is projected. Up to four different sets of planes can be shown, flipped over from different sides. The lecturer can, of course, write on the transparency or indicate atomic distances. The planes appear in different colors for better visibility.

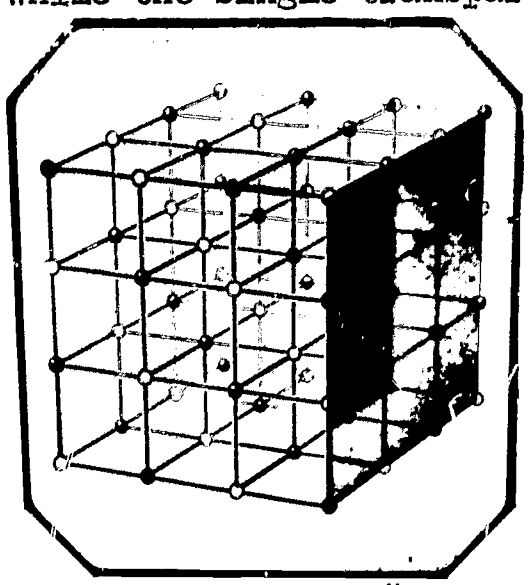


Fig. 5. Picture of a "colored overlay"

Another example for use of colored overlays is the addition of vectors. Four or five vectors of different length and direction are printed in different

1 No. 7067 B Coordinate system slides, W. M. Welch Scientific Company

colors, one per sheet. They are superimposed, adding them by the polygon method. The resultant is then shown to complete the polygon. In this example the sheets are not mounted, so that the vectors can be added in different orders, demonstrating the fact that the resultant is always the same and independent of the order in which the vectors are added.

A series of colored overlays for use in introductory physics has been produced and a list of titles is given in Appendix C. This list, at the present time, does not represent a complete course in physics, but gives examples of the types of overlays found useful in teaching large groups of freshmen and sophomores. The overlays can be produced by any one of the methods described previously; most titles mentioned in the appendix were made on diazochrome color film. Some of these colors project much better than others, and it is important to choose the proper order of colors. Important parts of the figure to be projected should be in dark colors, e.g. red, blue and black, while incidentals, such as coordinate systems can be in light colors.

With each overlay some light is absorbed, of course. For this reason it is not advisable to exceed 6-8 overlays because the image will lose some of its brightness.

6. Movable Transparencies

Another advantage of the overhead projector is the possibility of moving transparencies through small distances. For example, two coordinate systems can be moved with respect to each other when starting a discussion of the special theory of relativity. Special tracks are commercially available for mounting movable transparencies.

Cut-out sections can be moved from the side by clear plastic handles. A grommet machine is useful when it is desired to have elements of a transparency move in a circle.

7. Technamated Transparencies

In many cases a principle can be taught more effectively if continuous motion is involved, such as a wave moving across a boundary and changing its velocity and wave length. In such cases, "technamated" slides are employed.

The process of technamation uses the principle of rotary polarization. Special materials, consisting of thin birefringent, polarized plastics arranged and permanently mounted on acetate sheets, are available to make up

definite motion patterns.[1] The motion is actuated by placing a rotating polarizing disk between the light path passing through the transparency and the screen. For most overhead projectors a polarizing spinner can be mounted on the projector lens.[2] Fig. 1 shows a Beseler variable speed motor spinner on a Beseler projector.

Technamated slides or overlays are prepared by using the special materials for the construction of polarized animated transparencies. A variety of materials are available for a multitude of effects at different speeds including a reversal of motion.

Technamated transparencies included in the list of colored overlays in appendix C are marked with a T.

1 Technamation materials and kits are available from:
American Optical Company, Instrument Division, Buffalo 15, N. Y.
Technical Animations Incorporated, 11 Sintsink Drive E, P. O. Box 632, Port Washington, N. Y.
Technifax Corporation, Holyoke, Mass.

2 Polarizing spinner with variable speed motor, Charles Beseler Co. 219 South 18th Street, East Orange, N. J.
Polarizing Disc, American Optical Company, Instrument Division, Buffalo 15, N. Y.
Motorized Analyzers for Transpaque and Beseler Projectors, Technifax Corporation, Holyoke, Mass.

PART II

THE OVERHEAD PROJECTOR IN THE DEMONSTRATION LECTURE

1. Visual Aid Versus Lecture Demonstration

The use of a projector for lecture demonstrations is not new. Various still and movable models, projection meters, etc. for 3 1/4 x 4" slide projectors have been in use for decades. The projection of actual demonstrations in chemistry, using a slide projector, was described in the literature over twenty years ago.[1] At that time, however, slide projectors with a small stage had to be used. With the development of the 10" x 10" stage and an efficient optical system on modern overhead projectors, experiments can be carried out with greater ease and better visibility.

Any physicist using an overhead projector will soon find it a useful projection technique in a variety of situations. Old demonstration experiments, formerly made visible by means of carbon arcs or other shadow projection apparatus, can now be projected without any special set-ups or adjustments by making use of the stage of an overhead projector.

The physics lecturer should differentiate between the use of an overhead projector as a visual aid and its use for the demonstration of physical phenomena or actual experiments. Both of these methods are discussed in the following pages and in many cases their combined application is stressed. When technamation is used in a discussion of wave motion, by making use of birefringent materials and a rotating polaroid, students see a moving wave. This is, however, a pure visual aid and not a demonstration of the behavior of waves. On the other hand, the same use of technamated transparancies becomes a demonstration of physical phenomena when used in discussing the principles of polarization.

Using the projector to shadow - project the components of an electric circuit is a visual aid; when the switch is closed, however, and a real measurement is taken, the visual aid has turned into an actual experiment of a qualitative or quantitative nature. The overhead projector, although originally designed purely as a visual aid, can easily be used to make real physical demonstrations and experiments visible to large groups of students.

It is certainly not proposed that all lecture demonstrations be performed on the 10 inch by 10 inch stage of an overhead projector. Students should watch the lecturer actually perform numerous experiments using equipment sufficiently large and loud to be seen or heard by everyone in the room. Other types of visual aids such as closed circuit TV, shadow projection,

1 A. J. Chem. Ed., 16, 314 (1939) and 17, 210 (1940)

films, slides, stroboscopic illumination and large models have their place in any physics lecture. It was found, however, that the visibility of many old demonstrations could be improved considerably by the use of overhead projection.

Demonstrations can be performed in a vertical plane, by mounting the projector on its side and using a mirror to reflect the light upward through the projector lens mounted on a vertical shaft.[1] A 5" x 5" overhead projector for both, horizontal and vertical projection, is now on the market.[2]

One definite advantage of working with the overhead projector is the ease of storing its rather small accessories. It should be pointed out, however, that any equipment to be used for projection purposes must be stored in a dustfree place, preferably covered with a plastic bag or put into a closed cabinet.

It is believed that the overhead projector can become an extremely useful tool in the production of films and in the use of television. Methods described in this report are adoptable for use by a lecturer in front of a camera - movie or T. V. The use of the overhead projector is already widespread in commercial television studios and will grow with the further increase of closed circuit television in educational fields.

2. Motorizing the Projector

Two motors were attached to the overhead projector as shown in Fig. 1. The rear motor with a gear reduction has a constant speed of about 7 revolutions per minute. It is coupled to the axle driving the cellophane or acetone roll on the projector and thereby enables the lecturer to have the roll move across the projector at a constant speed.

The second motor is mounted on the same side of the projector but on a slotted aluminum angle. This allows the lecturer to move the motor to any desired position. The speed of this motor can be varied from about 10 to 35 revolutions per minute by means of a rheostat. It is used to drive accessories mounted on the stage of the projector.

Some examples of the use of these motors are given below:

<u>Rotating stage</u>. The model shown in Fig. 6 is driven by a variable speed

1 A special wooden platform for vertical projection is described in "Applications of the Overhead Projector to the Teaching of Chemistry" by Rev. L. J. McGowan of Archbishop Stepinac High School, White Plains, N. Y.

2 Act-O-matic Projector, sold by Technifax Corporation, Holyoke, Mass.

motor mounted on the projector. The rotating plastic disk may be used when discussing circular motion, rotating vectors, circular orbits of satellites or electrons in the Bohr model.

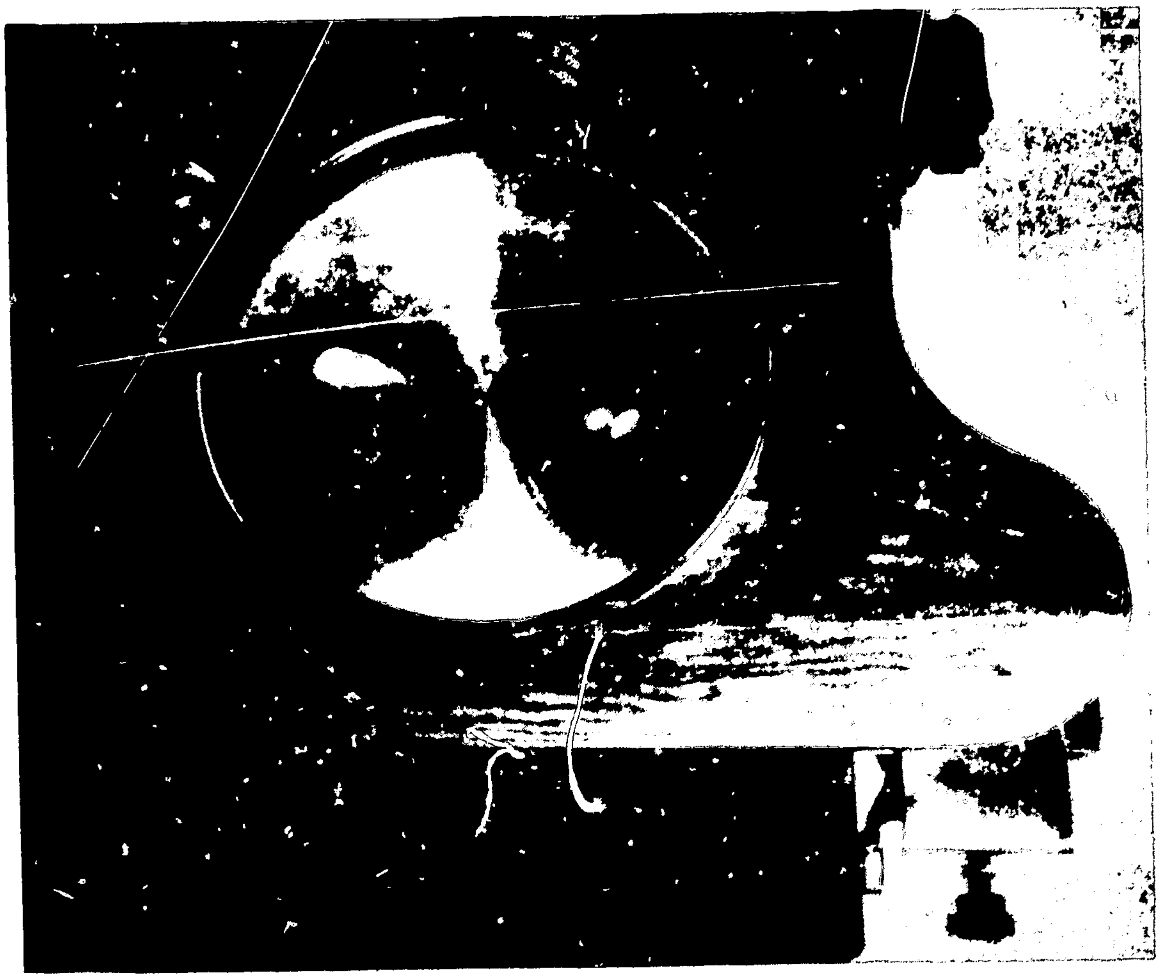


Fig. 6. Rotating stage

Wa.e Motion. A variable speed motor is used to drive a felt pen back and forth as shown in Fig. 7. The frequency can be varied by changing the speed of the motor; the amplitude can also be changed. A second motor drives the roller at the rear of the projector and pulls the acetone roll across the stage. As a result the students see the formation of a sine-wave by the use of a simple harmonic motion. The concepts of amplitude, frequency, wavelength and wave velocity are discussed when using this model.

The same motor used to drive the pen described above is also used with a friction drive to rotate the spiral shown in Fig. 8. In projection this shows a transverse wave. Again the frequency can be varied. A snapshot of this wave results when the motion is stopped by turning off the switch. At this instant the displacement is shown as a function of distance. When the stage is covered with a sheet of paper containing a small vertical slit the moving wave is shown at one particular point (displacement as a function of time) demonstrating the simple harmonic motion of each part of the wave.

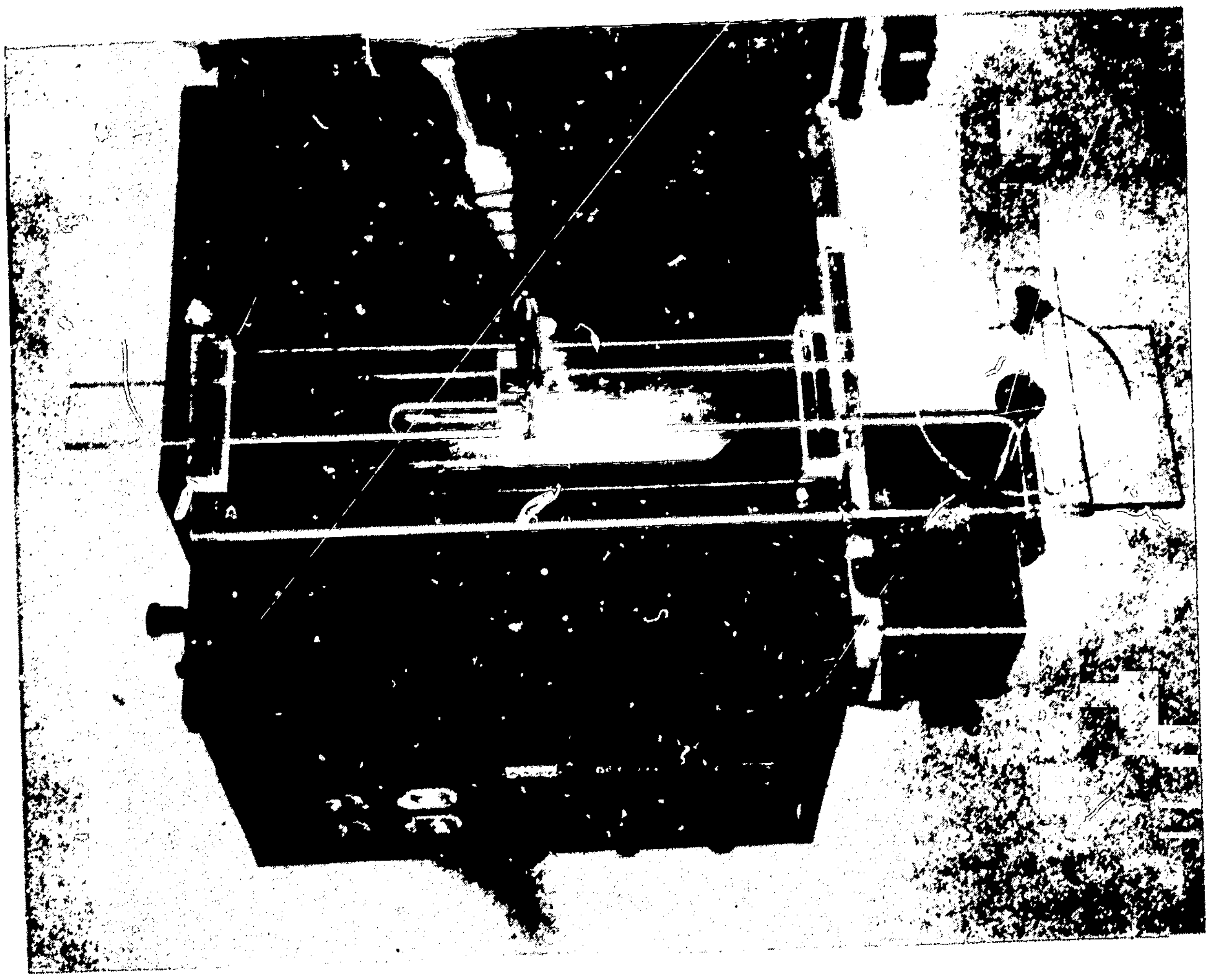


Fig. 7. Sine wave from simple harmonic motion

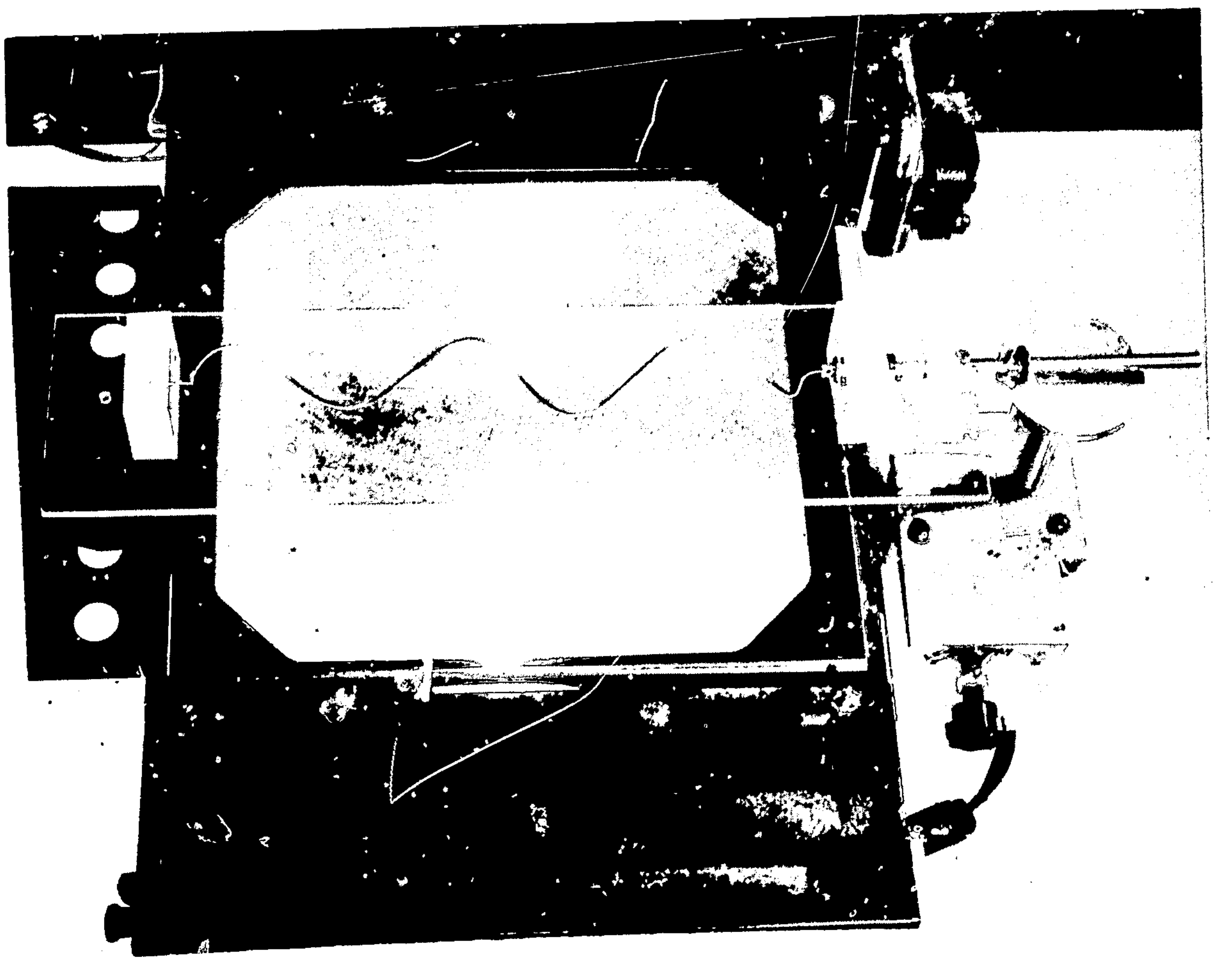


Fig. 8. Demonstrating transverse waves

3. Tracks Left by Rolling Balls

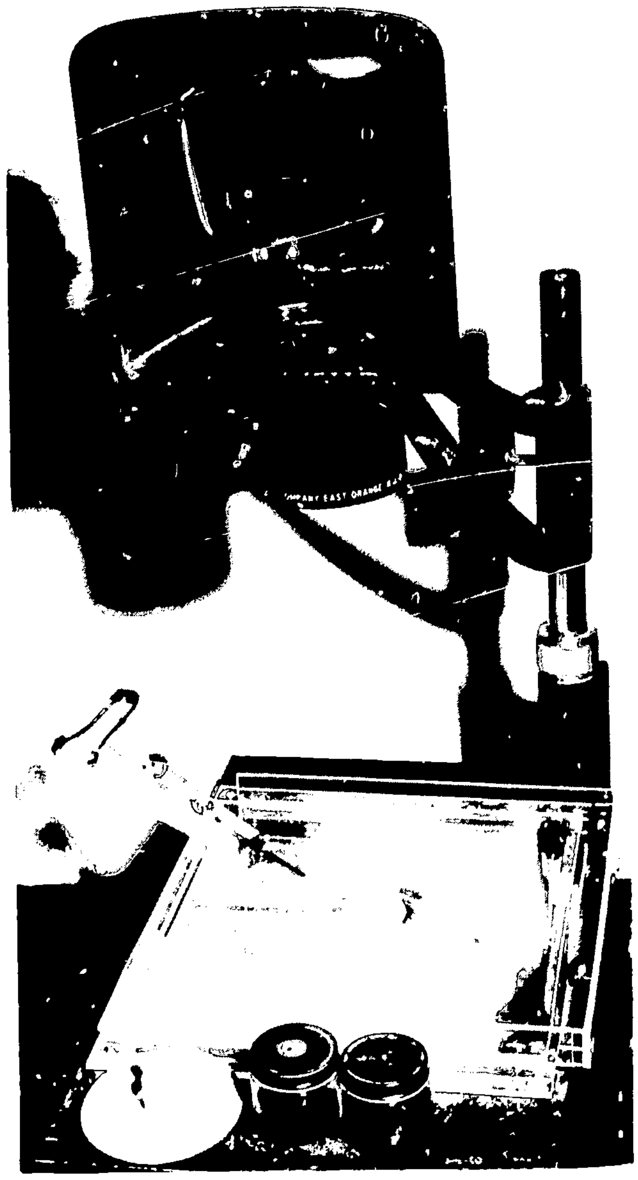


Fig. 9. Tray for tracks on projector

Collisions and scattering. A plastic tray is placed upon the stage of the projector. A number of steel balls are dipped in inks of various colors and rolled across the surface of the tray, thus leaving colored tracks. The balls may collide, illustrating the Compton effect; or they may be "scattered" by the $1/r$ surface, illustrating Rutherford scattering. The tracks left by the balls are used to indicate some of the quantities necessary for the mathematical derivations which follow the demonstration.

It has been found practical at times to place a thin sheet of transparent acetate on the tray, so that the tracks may be preserved for further use and the tray will not have to be thoroughly cleaned after each use.

Methanol has been used as a solvent for the colored inks.[1] If clear tracks are desired, it is necessary to clean the balls with methanol and then avoid touching them before use. The balls may easily be handled and dipped in ink by means of sugar tongs. Three or four different tracks may be produced with different impact parameters and projected in different colors.

The velocity with which the rolling ball approaches its target may be varied by adjusting the position of the ball release mechanism in the ball chute.

1 Higgins American India Ink or equivalent

The 1/r surface was cut on a lathe using a previously plotted 1/r plane curve as a template.

The 1/r surface may be covered temporarily by a metal plate (lower left on Fig. 9) if the student is not to "see" the actual scatterer.

To demonstrate a collision (such as in the Compton effect) no plastic sheet is used in the tray. One of the balls after it is dipped in ink, is put into the small hole at the center of the tray before releasing the other ball.

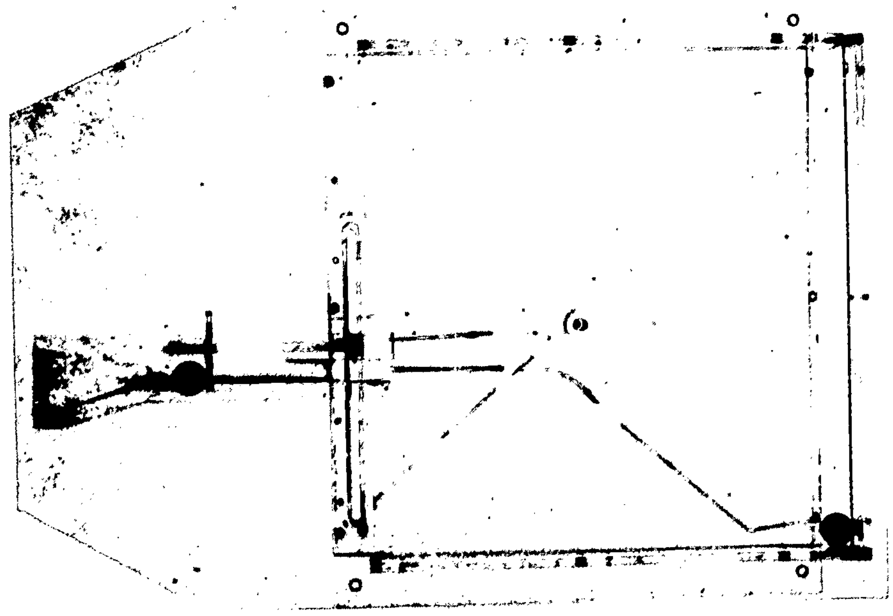


Fig. 10. 1/r scattering demonstration

Fig. 11. Projectile motion demonstration

Projectile motion. The same apparatus used for collisions and scattering can easily be used for a demonstration of projectile motion by slightly

raising the back of the tray. Trajectories can be obtained for different initial velocities, different angles and different downward accelerations, using various colors for comparison purposes.

Some of the details of the apparatus are shown in Fig. 12 and 13 with a list of materials given in table 1.

Table 1. Materials list for track apparatus

1 Pc.	Plastic[1];	11 5/8 Sq. x 3/16 Tk.
2 Pcs.	Plastic ;	1/2 x 3/16 x 10 5/8 Lg.
1 Pc.	Plastic ;	1/2 x 3/16 x 11 5/8 Lg.
1 Pc.	Plastic ;	1 5/8 x 5/8 x 7 1/2 Lg.
1 Pc.	Plastic ;	3/8 Sq. x 3/8 Lg.
1 Pc.	Plastic ;	1/2 x 25/32 x 5/8 Lg.
1 Pc.	Plastic ;	1/2 x 2 x 1/8 Tk.
1 Pc.	Plastic ;	3 7/8 ∅ x 3/4 Tk.
1 Pc.	Brass ;	#10-32 Round Hd. Screw, 1 1/4 Lg.
1 Pc.	Brass ;	#10-32 Wing Nut
1 Pc.	Brass ;	# 4-40 Round Hd. Screw, 1/2 Lg.
1 Pc.	Brass ;	# 4 Washer

Thin Transparent Plastic Sheet (10" x 10")

3/4" Stainless Steel Balls

India Ink (Red, Blue, Green, etc.)

Sugar Tongs

1 lucite or plexiglas

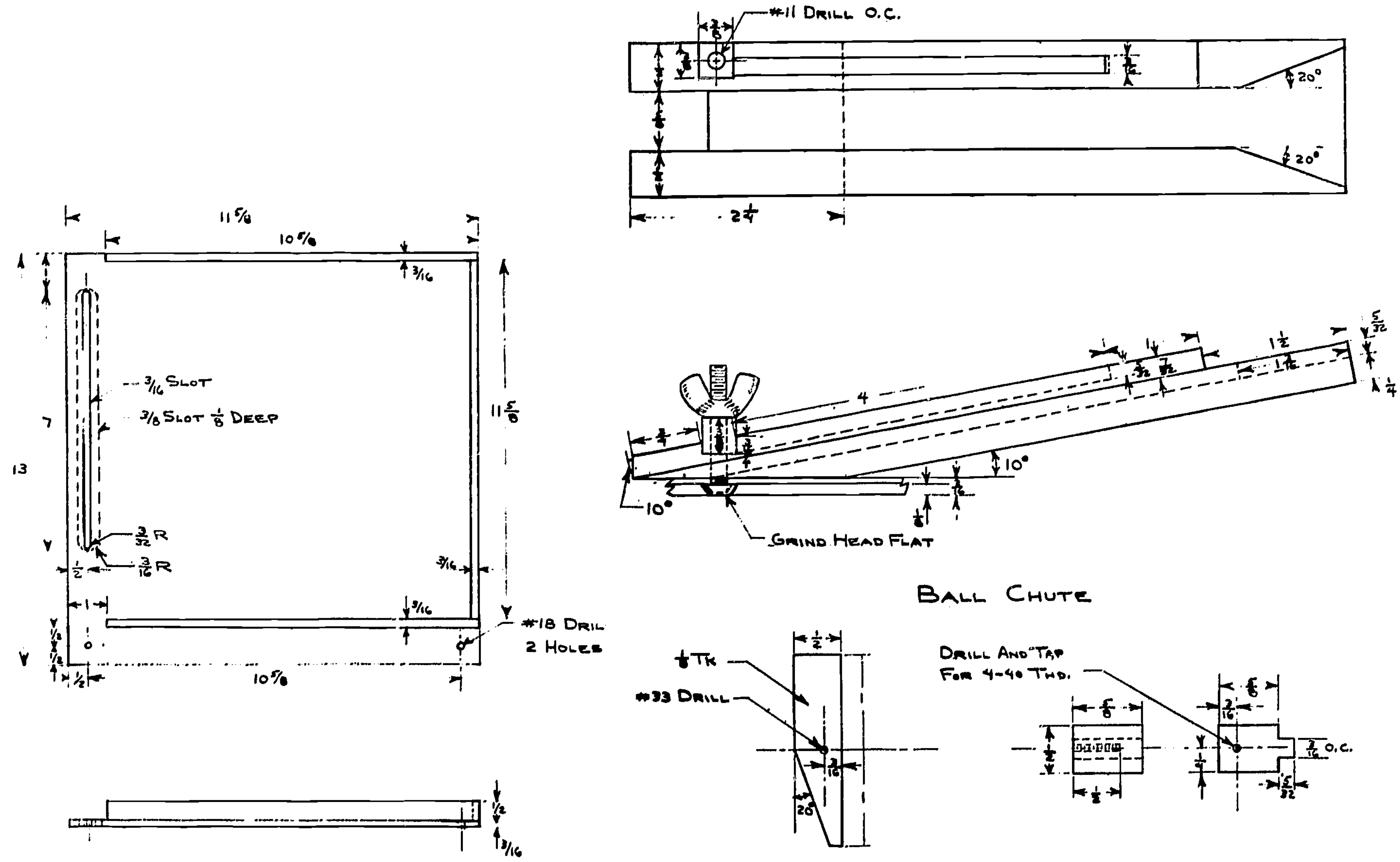


Fig. 12. Schematic of track apparatus

a. Plastic tray

b. ball release

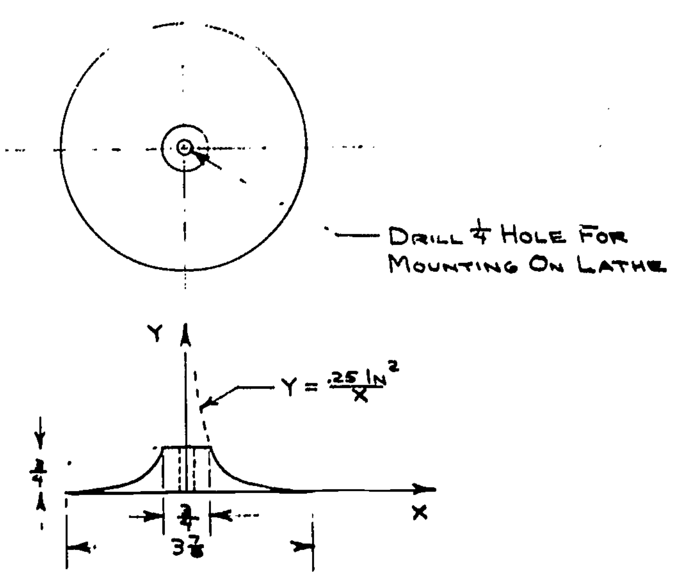


Fig. 13. Schematic for
1/r surface

4. Making Fields Visible

Demonstrations which have been performed for many years by various projection techniques can now be shown on the overhead projector with great ease. Magnetic fields due to permanent magnets are shown by sprinkling iron filings on a piece of glass or lucite placed on top of the magnet. Magnetic fields due to current carrying conductors are shown by passing a current of 20 amperes or more through a tube bent as shown in Fig. 14. After sprinkling iron filings on the plastic board and some light tapping, the circular pattern of magnetic lines is projected.

Electric fields are demonstrated by projecting the patterns formed when grass seeds or hayseeds are placed in an electric field. The seeds are put into a flat glass or plastic tray with carbon tetrachloride and oil.

Fig. 14. Magnetic lines of force due to current carrying conductor

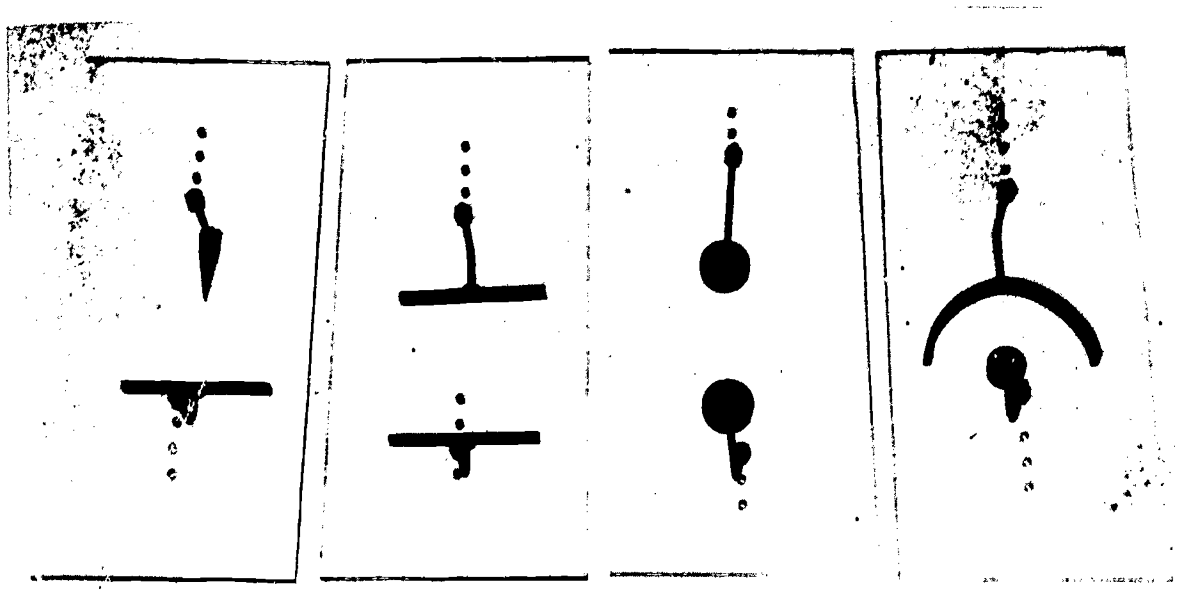


Fig. 15. Electrodes used for electric field demonstration

Several thousand volts[1] are applied across electrodes of various shapes - as shown in Fig. 15 - partially submerged in the liquid. A metallic ring placed into the field can be used to illustrate shielding.[2]

5. Shadow Projecting Models

Rotating vectors. In the study of two-slit interference phenomena, the rotating vector approach is a very effective one. A suitable model was constructed for the overhead projector. It shows the variation in the magnitude of the resultant with a change in the angle between two vectors. This model is shown in Fig. 16.

Fig. 16. Rotating vector model

One of the vectors, in the form of an arrow, is affixed to a 1/8 inch piece of plastic resting on the stage of the projector. The second vector

1 The Cenco No. 71248 5000-volt power supply can be used for this purpose, available from the Central Scientific Company

2 Currents, Fields and Particles by Francis Bitter, (John Wiley and Sons, Inc., New York, 1957) pg. 41

is on an 1/8 inch plastic disk which is rotated by hand around a point coinciding with the head of the first arrow. This is accomplished by glueing a small plug on the stationary plastic right at the head of the arrow, and by drilling a small hole into the rotating disk at the tail end of its arrow.

The resultant is obtained by fastening a string to the head of the rotating arrow and threading it through a plastic tube positioned above the tail of the stationary arrow. This tube is held by a plastic arm on the projector, as shown in Fig. 16. The string passes over pulleys along the arm to a counterweight behind the projector.

When the rotating vector is turned by hand, the resultant (shadow of the string) is observed to vary, giving a minimum at an angle of 0 and 360° between the two vectors, while a maximum resultant is obtained when the angle is 180°.

Superposition of waves. This demonstration illustrates the point by point addition of the amplitudes of two sine waves with different frequencies. Demonstrators may wish to build similar models varying the amplitudes or frequencies of the waves, or both.

The separate waves as shown in the schematic, Fig. 17, are projected first. The addition of waves is then performed by using an ordinary pocket comb to slide the spaghetti in the upper wave down to join that of the lower wave. In Fig. 18 this has been done for part of the wave.

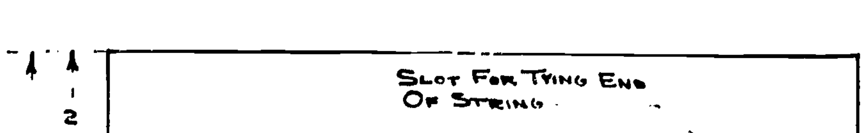
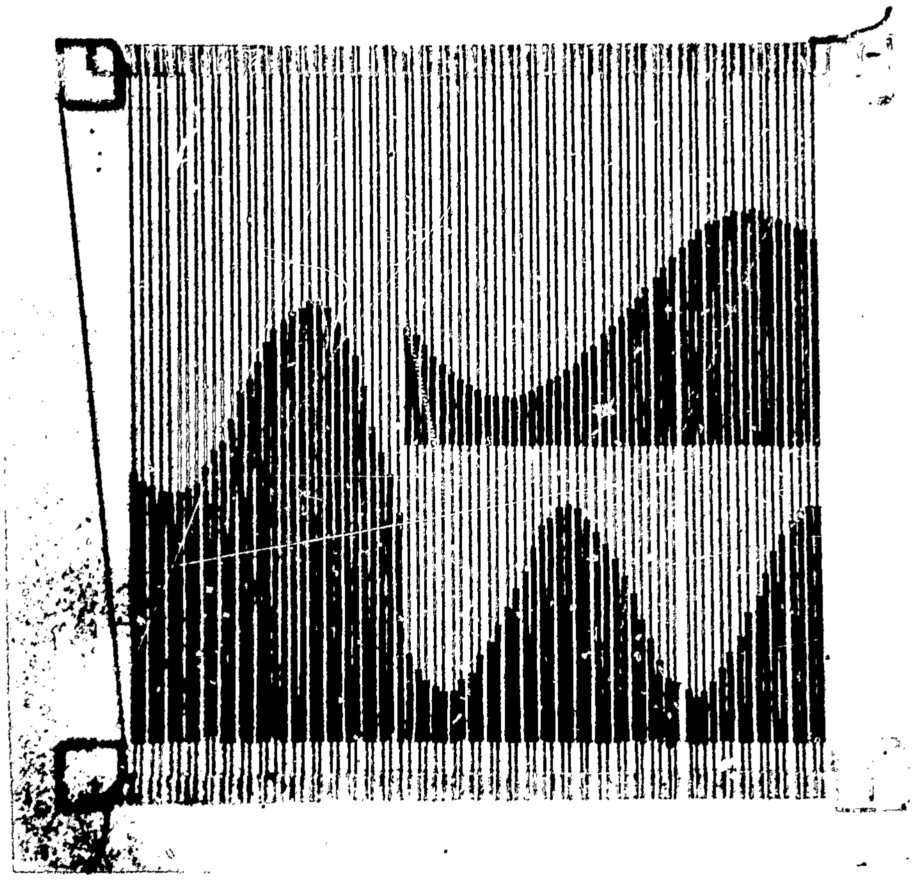


Fig. 17. Schematic Diagram for Superposition Demonstration

A superposition model more serviceable than the one described here but more difficult to construct has also been built and is shown in Fig. 19. The spaghetti has been replaced by brass tubing (1/8 O.D. for upper wave and 1/16 O.D. for lower wave) sliding on transparent nylon fishing line (spinning reel type). Instead of drilling numerous holes to support and separate the nylon line, the line is wrapped around two threaded



rods (1/4 - 20 THD. - using every other thread) mounted in place of the 8 inch strip with the holes. A thin layer of glue is applied to the threaded rod to hold the lines in place. The advantages of this model are twofold. The waves are superimposed with less friction and the components of both waves may be distinguished even after super-position has taken place, as shown in Fig. 19.

Fig. 18. Superposition Demonstration - ratio of wave lengths is 1:2

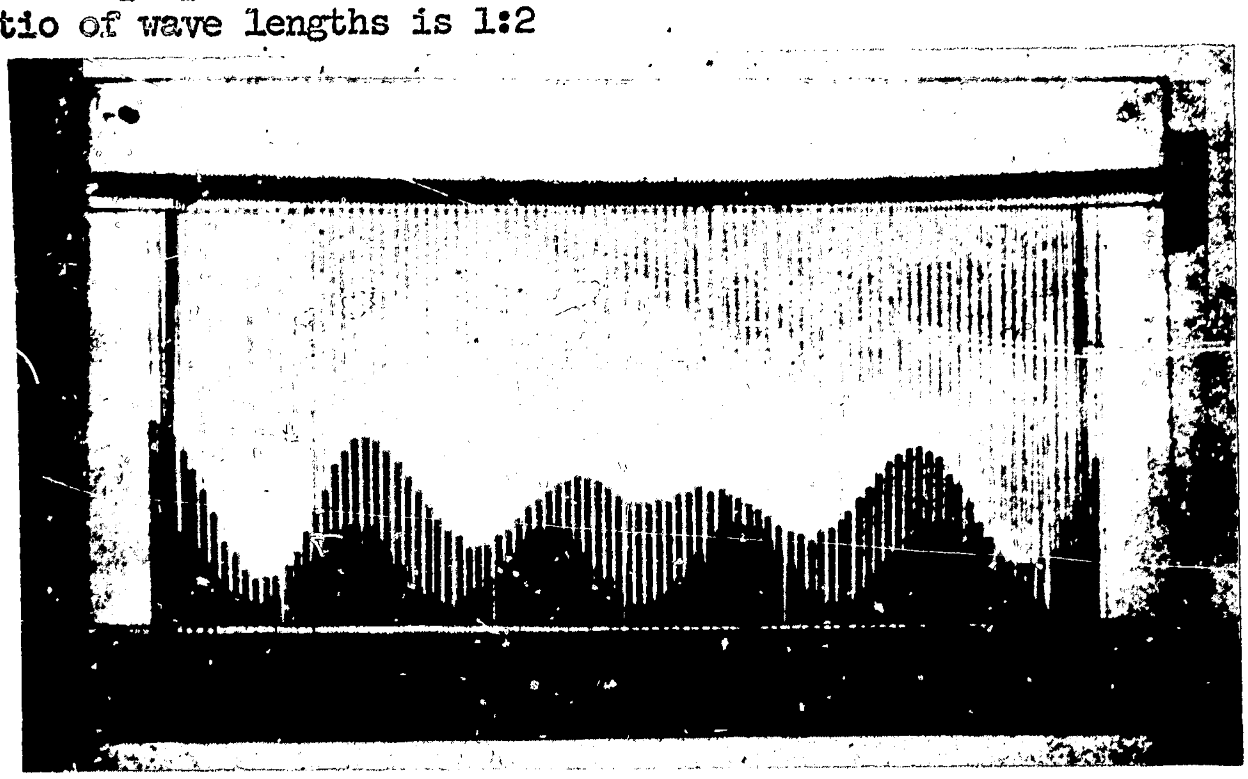


Fig. 19. Superposition demonstration - ratio of wave lengths is 3:4

Kinetic theory. Fig. 20 shows one of the many different types of kinetic theory models easily constructed for use on the overhead projector. A variable speed motor drives a piston. The two adjusting screws at the right of the model enable the lecturer to level the model, so that the steel balls move at random when driven by the piston. Different sized spheres can be

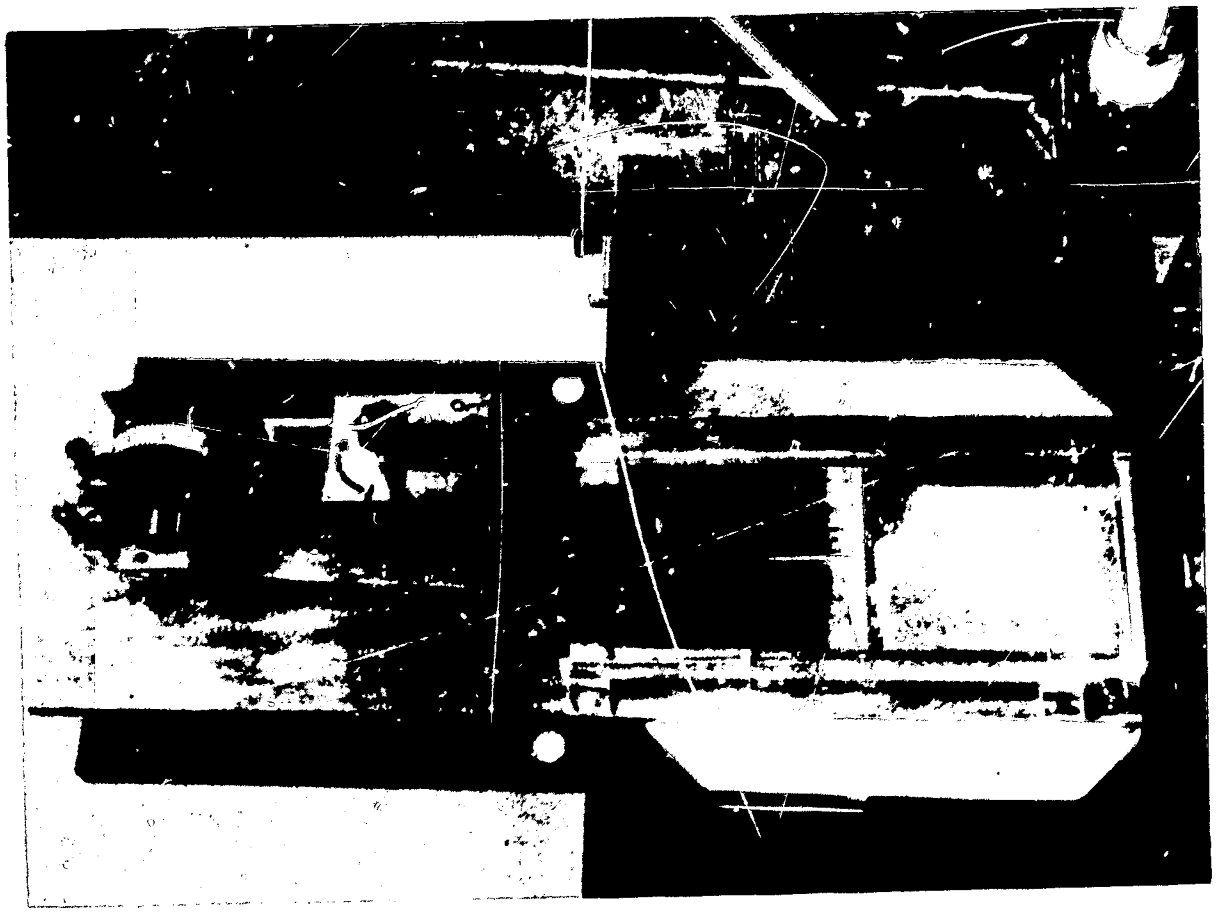


Fig. 20. Kinetic theory model

used to illustrate many phenomena explained by the kinetic theory.

Another model makes use of an electric hand vibrator. This vibrator may be held next to a plastic box with beads or steel balls, or it may be mounted on a board with such a transparent box. Students can then follow the random motion of the beads on the screen. Besides qualitative demonstrations of kinetic theory, a more detailed study of a Maxwellian distribution can be made when using transparent beads and photographing the image.[1]

In a similar model, designed by Professor E. O. Cook of Tampa University, the walls of the enclosure were studded with larger steel balls to improve the random motion of the smaller spheres.[2] To determine the efficiency of

1 The Lloyd William Taylor Manual of Advanced Undergraduate Experiments in Physics (Addison-Wesley Publishing Company, Inc. Reading Mass., 1959), pg. 126.

2 Demonstration and Laboratory Apparatus Report of the 1960 Summer Visiting Professor Workshop (Rensselaer Polytechnic Institute, Troy, N. Y., 1961), pg. 144.

the model, Prof. Cook obtained information about the distribution, speeds, and the mean free paths of the spheres photographically. He also suggested the use of this apparatus for a demonstration of gaseous diffusion and Brownian motion.

Fig. 21. Close-up of kinetic theory chamber

Kepler's second law. This model, shown in Fig. 22 as it appears on the screen, is used to illustrate Kepler's second law or the law of areas: "A line joining any planet to the sun sweeps out equal areas in equal time."

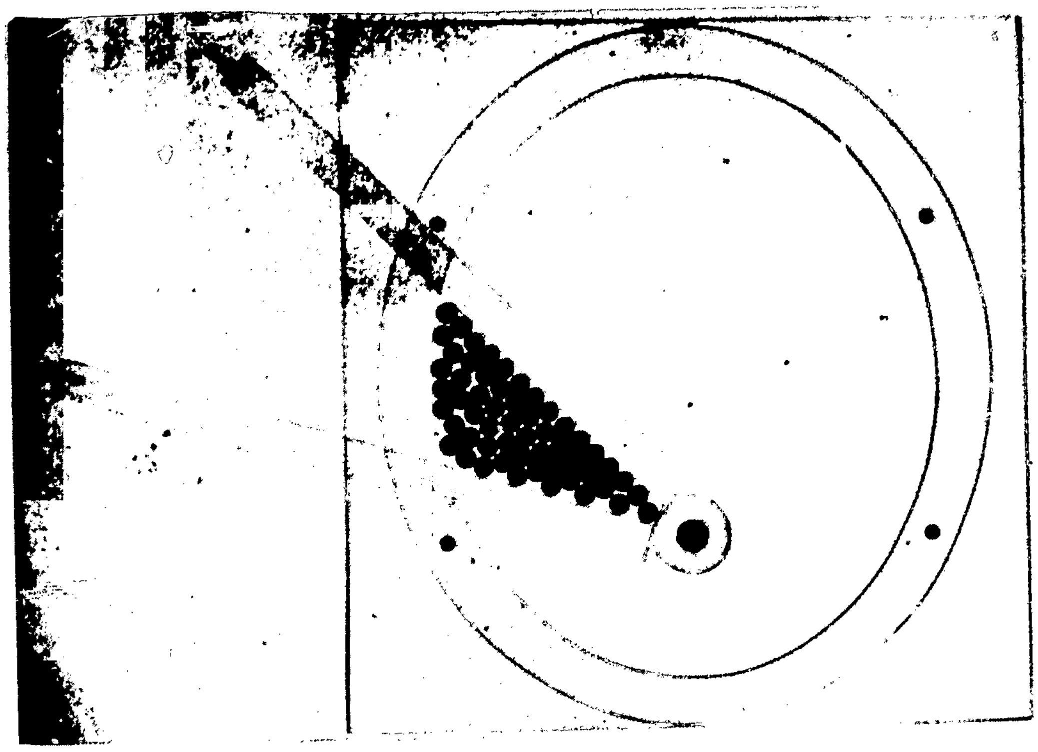


Fig. 22. Illustration of Kepler's second law

In the construction of this model, a 1/8 inch thick elliptical ring is mounted on a base of clear lucite or plexiglas. Two movable arms are mounted on a pin so that they rotate around one of the focal points of the ellipse. 1/4" steel balls are placed between the arms, as shown in the figure. A weak spring may be put across the two screws at the end of the arms; but is not really necessary for proper operation.

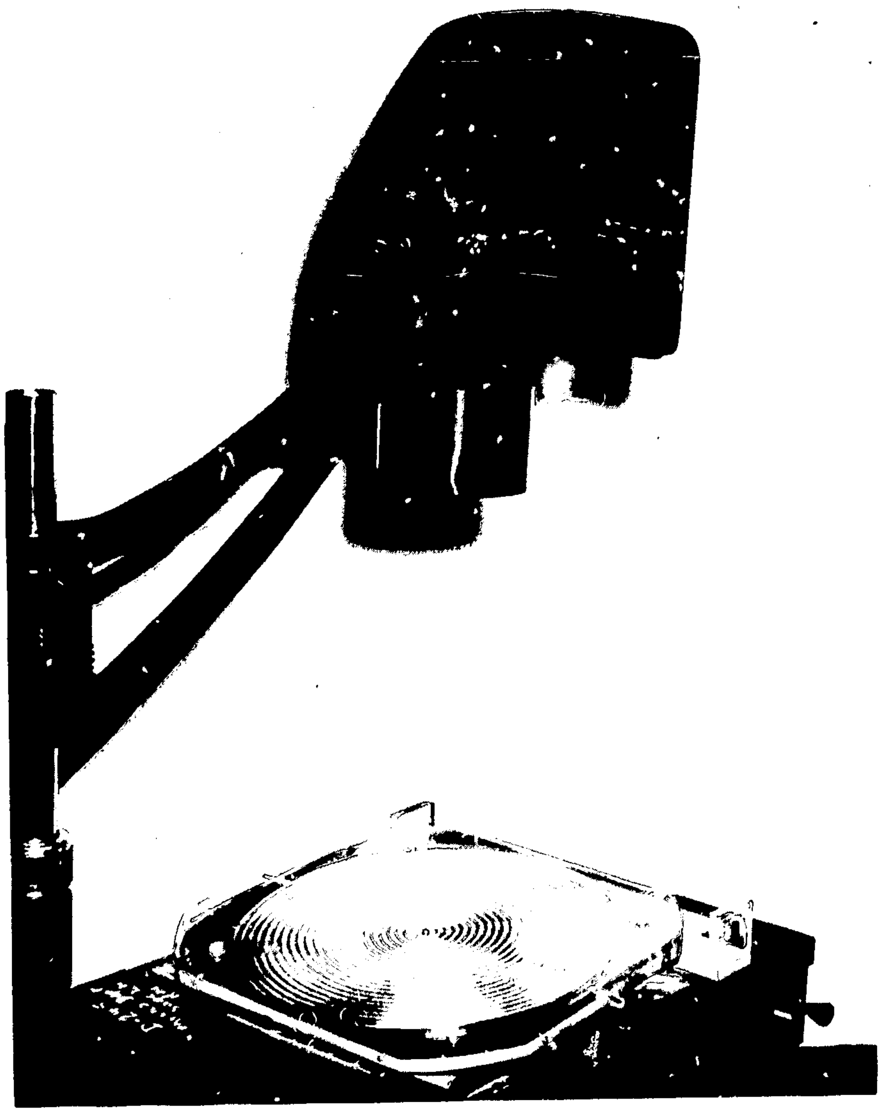


Fig. 23. Cyclotron model on projector

Cyclotron model. This hand operated cyclotron model produces a gravitational acceleration of a steel ball analogous to the electrical acceleration of charged particles in the actual cyclotron. The operation of the model requires some skill on the part of the lecturer. It is necessary to move the track through a small amplitude and to use a ball about 5/32 inch in diameter. The cyclotron model has a spiral track.

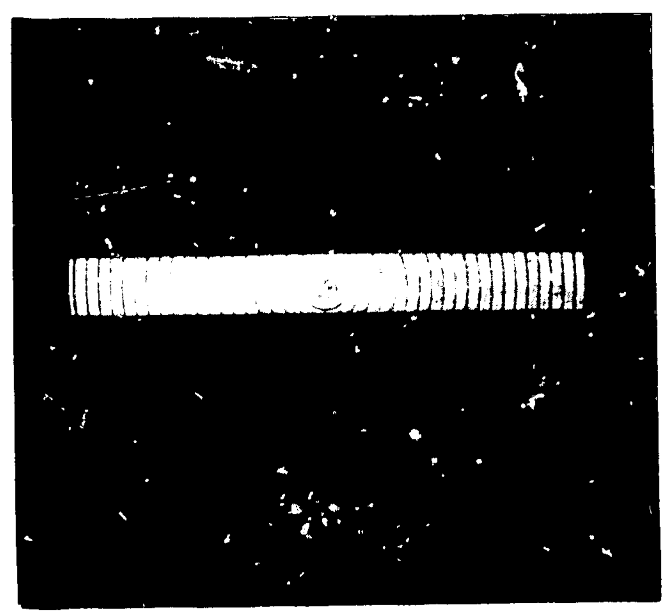


Fig. 24. Cyclotron model as it appears on the screen

Some of the details of this cyclotron model are shown in Fig. 25. Materials required are listed in table 2.

A different cyclotron model for use on overhead projectors was designed by Professor E. John Eastman of Brigham Young University[1]). This model shows that particles are accelerated only between the two dees and that there is no change in the magnitude of the velocity while in the dees.

1 Demonstration and Laboratory Apparatus Report of the 1960 Summer Visiting Professor Workshop (Rensselaer Polytechnic Institute, 1961), pg. 131

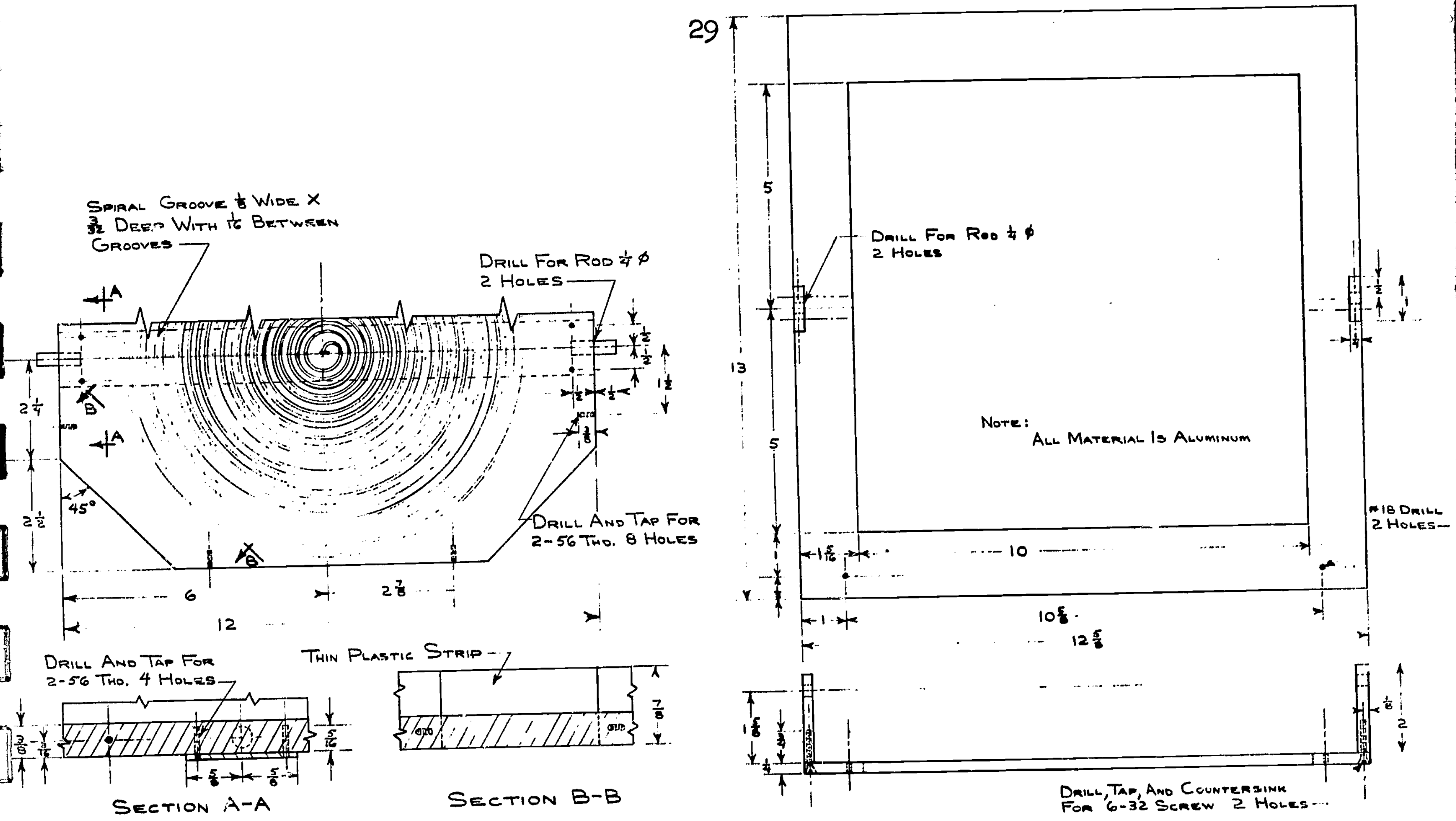


Fig. 25. Schematic of cyclotron model

a. top view of track b. track mount

Table 2. Materials list for cyclotron model

1 Pc. Plastic[1]; 12 x 9 1/2 x 3/8 Tk.

1 Pc. Plastic ; 12 x 1 1/4 x 1/16 Tk.

2 Pcs. Plastic ; 1/4 dia. x 1" Lg.

1 Pc. Flexible Plastic; 7/8 x .02 Tk x Approx. 37 Lg.

8 Pcs. Brass ; #2-56 Round Hd. Screw, 3/8 Lg.

4 Pcs. Brass ; #2-56 Round Hd. Screw, 5/16 Lg.

1 Pc. Opaque Black Paper; 9 1/2 x 12 Lg.

2 Pcs. Thin Transparent Red Plastic; 4 1/2 x 12 Lg.

1 Pc. Al; 13 x 12 5/8 x 1/4 Tk.

2 Pcs. Al; 1 x 2 x 1/4 Tk.

4 Pcs. Brass ; #6-32 Flat Hd. Screw, 3/4 Lg.

1 Pc. Stainless Steel Ball; 5/32 ⌀

1 lucite or plexiglas

6. Miscellaneous Demonstrations

Oil drop demonstration. In order to make demonstrations visible to large audiences it is helpful, of course, to make the equipment as large as possible. There are certain limitations, however, beyond which we cannot go. Huge pieces of equipment take more time and personnel to set up and may overtax the storage facilities. In many cases, of course, it is impossible to increase the scale of the demonstration at all. One such example is the use of an oil drop for a demonstration of the order of magnitude of molecular dimensions.[1, 2]

A drop of oil at the end of a fine wire or a pipette is held next to a transparent scale on a projector (overhead or slide) for an approximate determination of the diameter of the drop. A single drop is then allowed to fall on the surface of water in a plastic or glass tray on the stage of an overhead projector. If the surface was lightly dusted with talcum or any other powder, students will observe the oil film spreading out, shoving the powder before it. A plastic ruler on the tray is used to measure the diameter of the oil film. Taking into account the original volume and the measured area, the thickness of the film can be calculated.

Angular momentum. The plastic arm attached to the overhead projector and described on page 23 in manuscript can also be used for a demonstration of the conservation of angular momentum. A string is threaded through the plastic tube positioned at the center of the stage. A 1/2 or 3/4 inch steel ball, attached to one end of the string, is made to rotate on the projector stage. The other end of the string passes over pulleys along the arm to a counterweight behind the projector. When this counterweight is pulled down, the radius of rotation of the ball decreases, causing an increase in the angular velocity of the sphere.

Probability board. Fig. 26 shows a transparent probability board constructed of lucite or plexiglas. Small steel balls in the container at the top roll down a chute when the handle is turned. Single balls can also be released. The balls are deflected by pins arranged as shown and enter the slots at the bottom of the apparatus. The board is covered by a lucite sheet and the balls can be returned to the container through a plastic pipe by tilting the whole board.

The back of the board is about two inches higher than the front edge for the proper rolling of the balls. The projector is focused on the balls appearing in the slots.

1 Demonstration Experiments in Physics, R. M. Sutton (McGraw-Hill Book Company, Inc., 1938), demonstration A-53

2 Eric Rogers, Am. J. Phys. 24, 479 (1956)

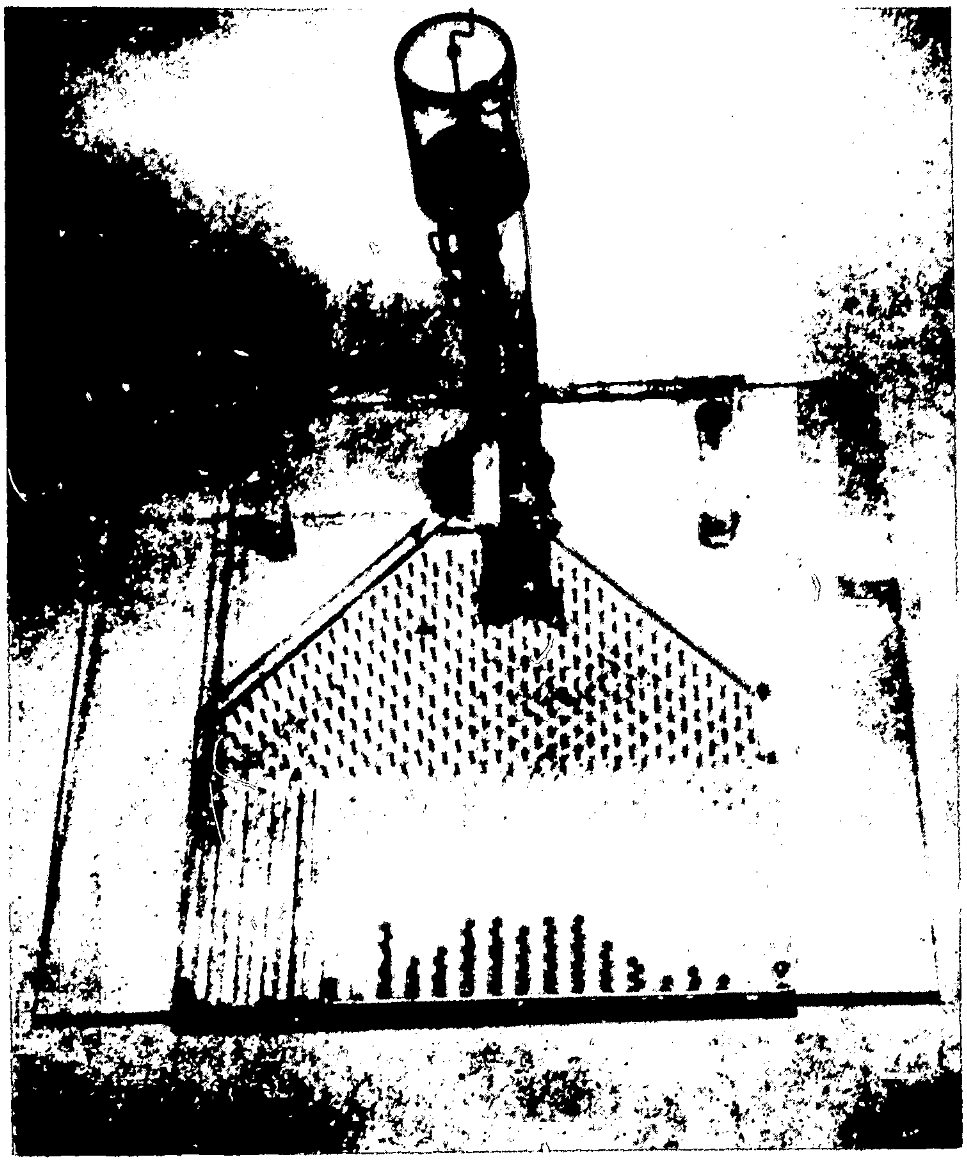


Fig. 26. Probability board

<u>Triple point of water.</u> On the stage of a projector an airtight plastic container with a few cubic centimeters of water is connected through a cold trap to a vacuum pump. The chamber is pumped out. It is observed how the water first boils and then freezes. Bubbles of steam may be seen breaking through the freshly formed ice. The demonstration is more spectacular if the chamber is placed between two polaroids, so that the ice crystals show up in color. Fig. 27 shows the chamber used on the projector.

<u>Induced electromotive forces.</u> A projection galvanometer, described in more detail in section 4 of part III, is placed on the stage of an overhead projector, or on a separate slide projector. The

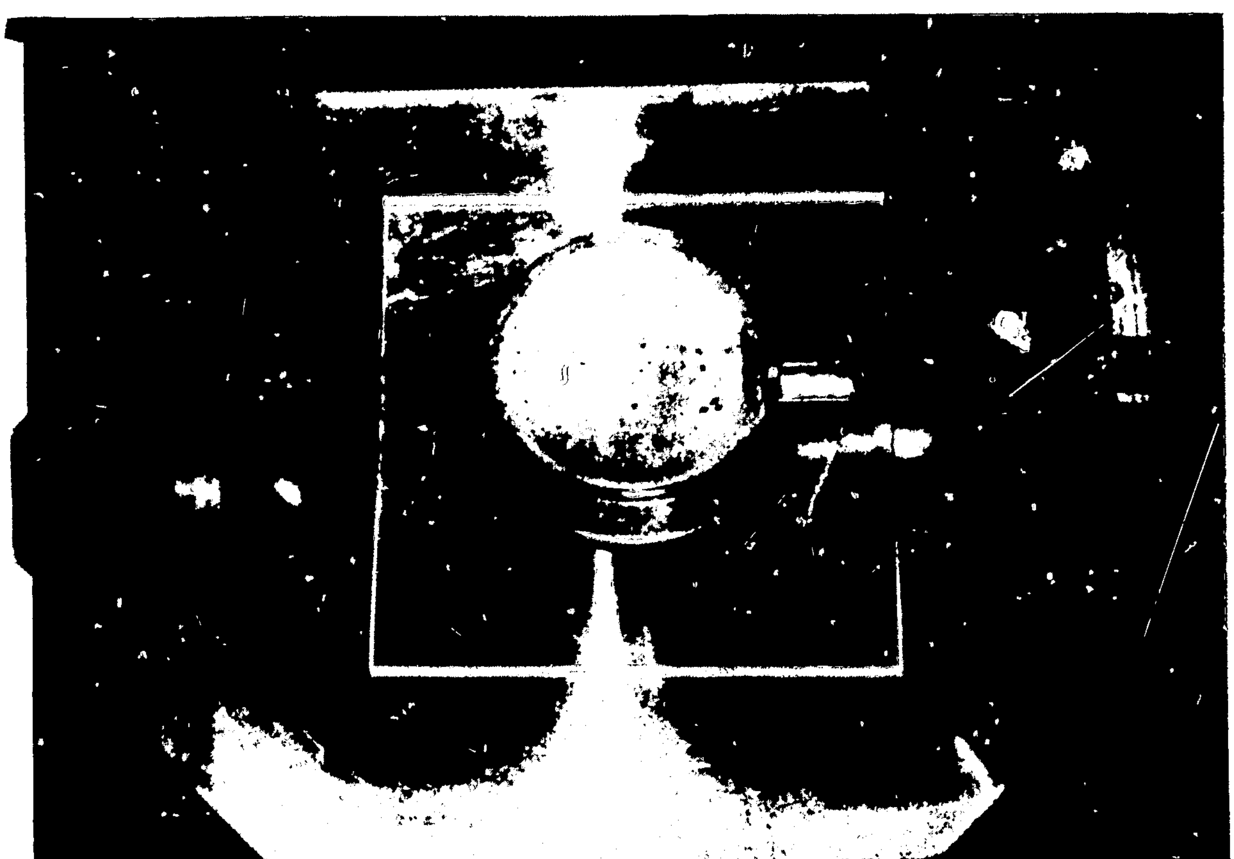


Fig. 27. Demonstrating the triple point of water

advantage of a second projector for this set of demonstrations is twofold: it leaves more space on the 10" x 10" projector stage and it removes the galvanometer from the direct influence of magnets used in the demonstrations. The galvanometer is connected across a straight wire and the e.m.f. induced is observed as the wire is passed across the pole pieces of a magnet on the overhead projector stage. The speed and the angles of the wire may be varied, of course.

The galvanometer may also be connected to various coils placed on the overhead projector. Induced e.m.f.'s can be shown to exist for any relative motion between magnets and coils. By using different coils and magnets, the number of turns, the magnetic field, as well as the relative velocities can be varied.

If a coil has a sufficiently large number of turns, the e.m.f. induced due to the motion of the coil in the earth magnetic field can be observed.

A useful coil of relatively few turns is shown in Fig. 28. About 5 yards of 1/16" brazing rod was used in its construction. The two terminals are connected to the projection galvanometer to show the e.m.f. induced when a bar magnet is moved through the coil at various speeds.

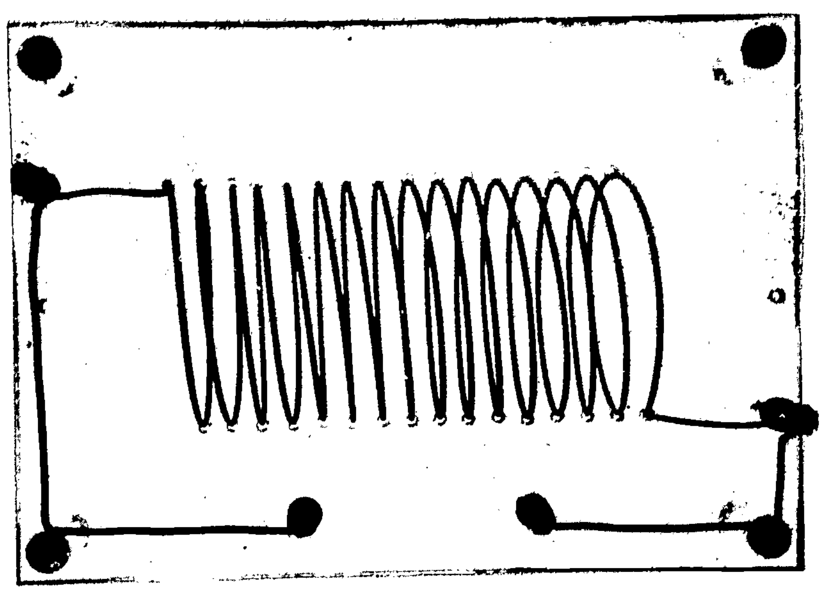


Fig. 28. Primary coil

The terminals of the coil may also be connected through a switch to a power supply, such as a six volt battery. A compass needle on a pin or thumbtack, possibly at the end of a thin long piece of plastic, is used to detect the magnetic fields inside and outside the current-carrying coil.

A secondary coil, connected to the projection galvanometer, may be placed inside the primary, as shown in Fig. 29. Again the magnitude and direction of the induced e.m.f. is observed when the switch in the primary circuit is closed and opened. By placing a projection ammeter[1] into the

1 See section 4 of part III for details of projection meters

primary circuit, this current can be observed.

A 1/2 inch diameter steel rod inserted into the secondary coil will, of course, considerably increase the induced e.m.f. and demonstrate the concept of permeability.

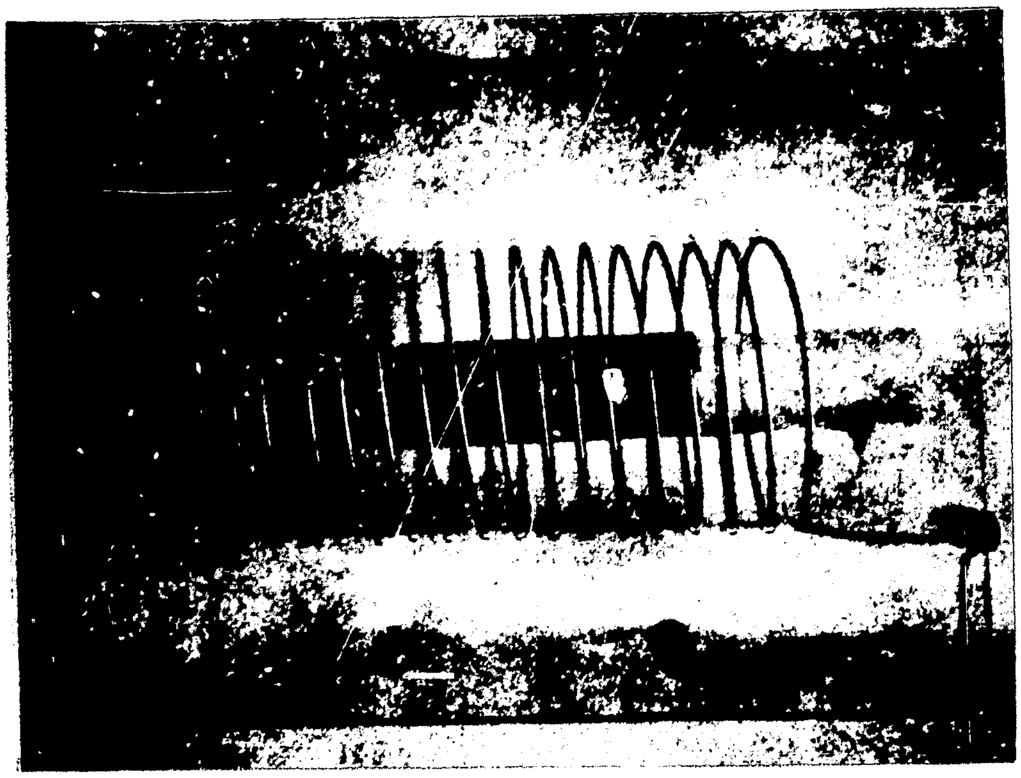


Fig. 29. Primary and Secondary Coils

The very much simplified model of a generator shown in Fig. 30 is placed on the stage of the overhead projector when discussing Faraday's law and induced electromotive forces. A magnetron magnet provides a magnetic field as shown in Fig. 31. The two brushes are connected to the projection galvanometer and the crank is turned by hand. The relation between the induced voltage and the position of the coil or the speed of rotation can easily be demonstrated.

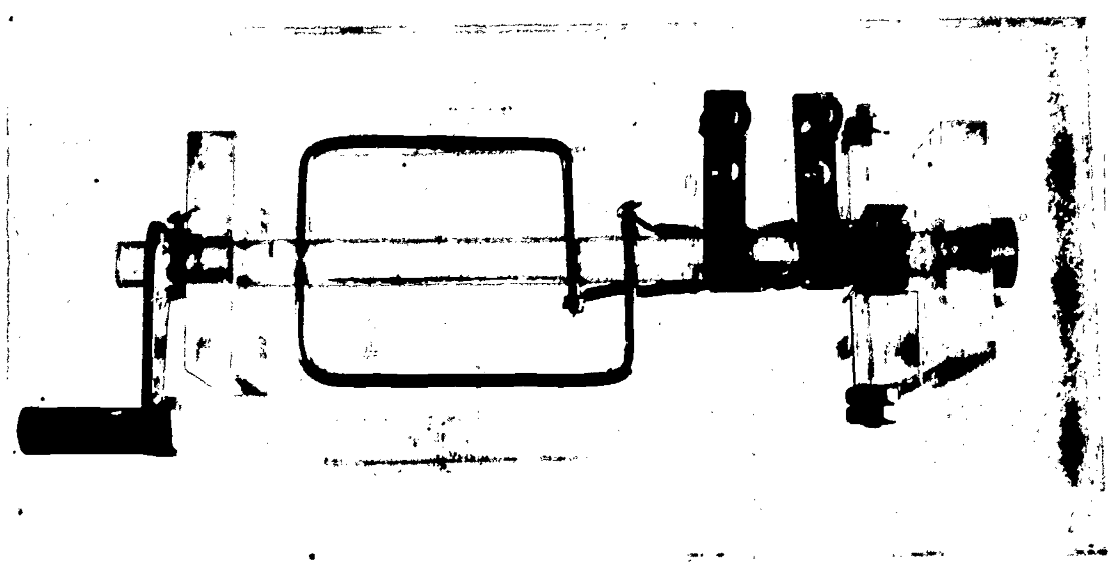


Fig. 30. Generator without magnet

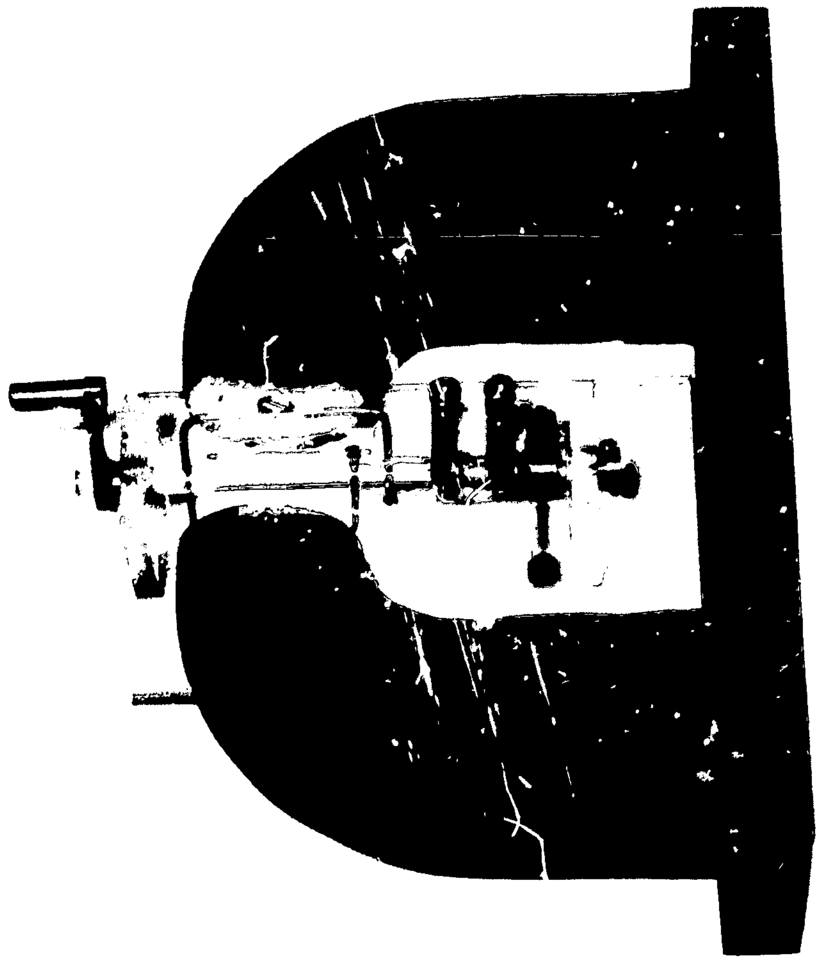


Fig. 31. Generator with magnet

Suspended pith balls and magnets. From a laboratory stand next to the stage of the projector we can, of course, support all types of equipment we would want to shadow project. Pith balls, for instance, were hung from threads to test charged rods, demonstrate attraction and repulsion of charged particles, etc.

Magnets were suspended by fine threads for various demonstrations. Small magnets or compass needles can also be supported on pivots and shadow projected.

Magnet model. 24 small magnets are mounted on separate needle-point pivots with a lucite or plexiglas base. Commercially available models[1] can be used with the pivots remounted on a plastic base. The magnets hold a random orientation but align themselves when a bar magnet is brought close.

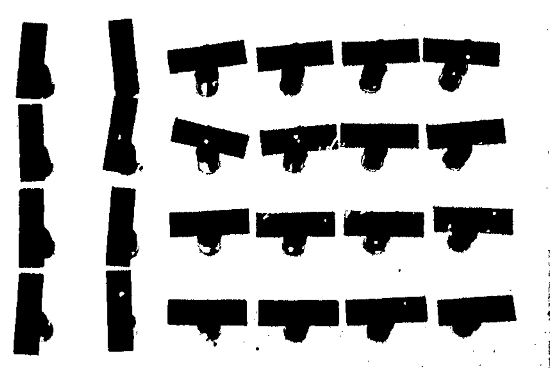


Fig. 32. Magnet model

The model is useful in discussing magnetic fields due to permanent magnets such as the magnetron magnet

1 No. 1800 Magnet model, W. M. Welch Scientific Company or No. 78381, Magnet model, Central Scientific Company

used in other demonstrations. When this magnet is placed onto the stage of the projector, the model will show the direction of the lines of force.

This demonstration is particularly useful when discussing magnetic properties and ferromagnetic domains.

7. Using the Projector Lens Only

There are situations where the light source of the projector may be replaced by a different source, using just the lens system for projection purposes. One example is the use of a cathode ray tube commercially available to demonstrate deflections of charged particles due to magnetic fields.[1] The tube is first shadow-projected, making use of the overhead projector light source. When the spark coil supplying the high voltage across the tube is turned on, the projector light is turned off and the greenish looking electron beam is focused onto the screen. A magnet brought close to the tube will deflect the beam. The magnet can also be shadow-projected first. For the electron beam to be clearly visible, however, the room has to be in complete darkness.

The projector lens has also been used to project patterns from high intensity oscilloscopes[2], but, once again, the room has to be darkened to clearly observe this "projection oscilloscope".

1 No. 71555, Central Scientific Company or No. 2145, W. M. Welch Scientific Company

2 Type 543 Oscilloscope, Tetronix, Inc., Portland, Oregon

PART III

BREAD-BOARD FOR ELECTRICAL CONNECTIONS[1]

1. The Projection of Circuits

The use of conventional circuit diagrams for electrical wiring is, of course, very useful at all levels of instruction. Many times, however, students do not have the opportunity to see an actual circuit in operation and therefore do not get a feeling for the physical dimensions of the components or the order of magnitude of the electrical quantities involved. This poses a difficult problem for the lecturer because actual electrical components are - in general - too small to be seen by a large class and large models do not use realistic parts. Ordinary electrical meters cannot be used, but must be projected in some manner to be visible in a classroom.

The overhead projector is first used to show a circuit diagram on a transparency. After a discussion of the diagram by the lecturer, the actual working circuit, mounted on a transparent bread board, is superimposed on the circuit diagram and the projector is focused. Projection meters are used for reading the various electrical quantities of interest and are placed on the lower part of the projection stage.

2. The Bread-Board

The transparent board itself consists of a 1/4" thick piece of lucite, 7" x 12" with holes drilled 1 1/2 inches apart. The board is placed onto a special frame mounted on the projector. The height of this frame is adjustable so that the projector can be properly focused on the electrical components and, at the same time, on the projection meters placed onto the projector stage.

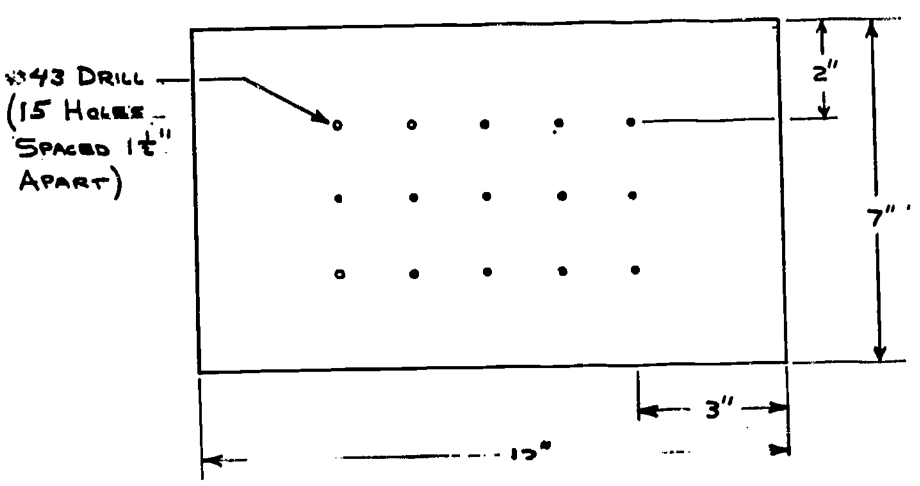


Fig. 33. The plastic bread-board

1 For the equipment described in this section the author was awarded first prize in the demonstration equipment category of the 1961 competition for Physics Teaching Apparatus, sponsored by the Committee on Apparatus for Educationa Institutions of the American Association of Physics Teachers. (PHYSICS TODAY, November 1961, page 20)

The adjustable frame is of simple construction, making use of a "Lab Jack"[1] fastened to the back of the projector with easily removable screws. The mount is shown in figures 1 and 34.

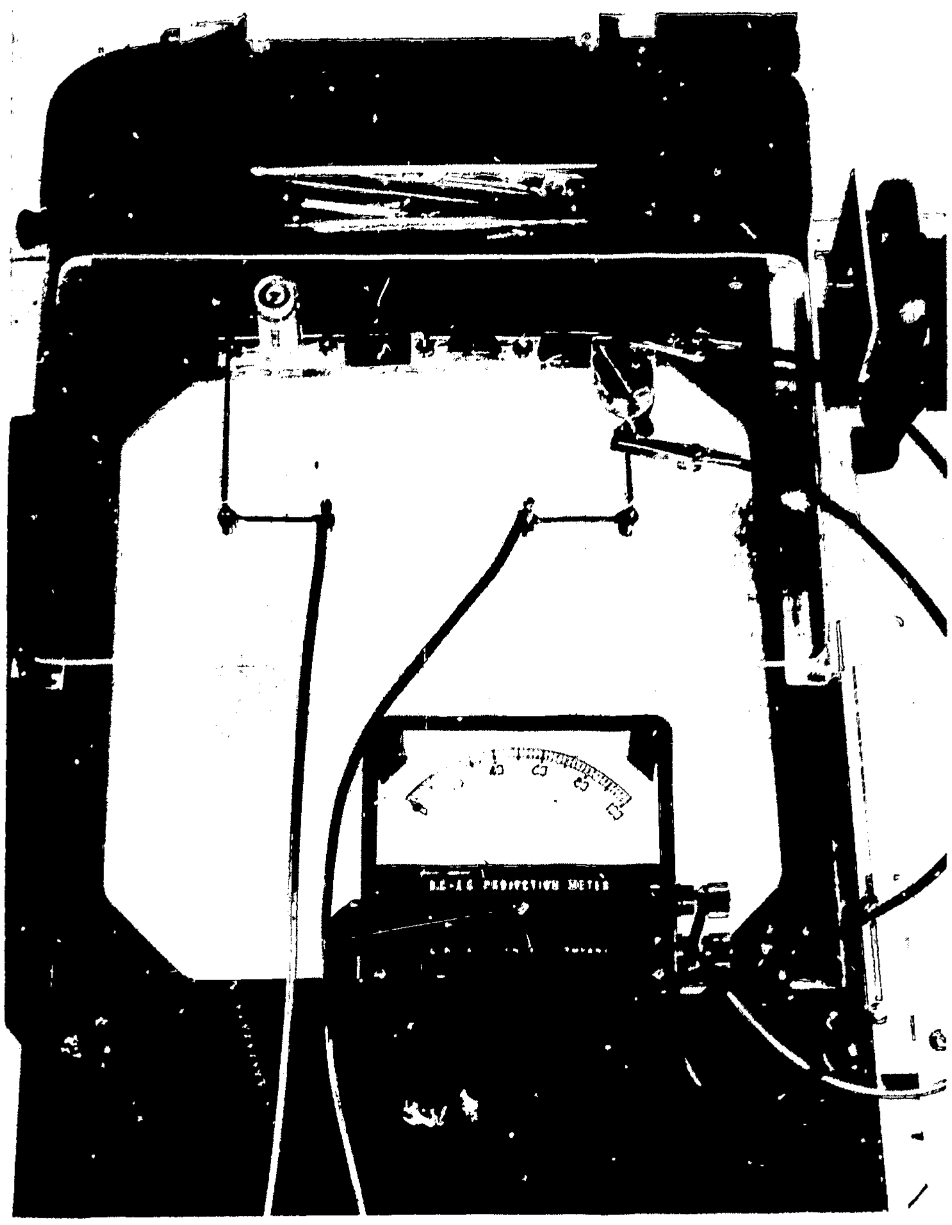


Fig. 34. Bread-board on frame. The adjustable "Lab Jack" is seen at the top center. The circuit consists of a capacitor, resistor and inductor

3. Plug-in Components

<u>Jacks</u>. Jacks are used to plug the components and connecting wires into the plastic board or into pins on other circuit elements. They must be as small as possible so as not to produce a disproportionate shadow on the screen when projected. No commercially available jacks were found that proved satisfactory without some modifications. The following changes were made in

1 No. 19089, Central Scientific Company

the number of 107 phone tip jack and the number 108 solder type phone tip manufactured by H. H. Smith[1] and shown in Figures 35 and 36.

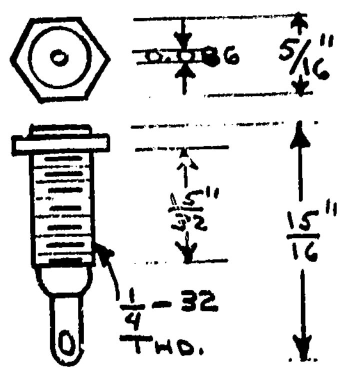


Fig. 35 Phone tip jack brass, nickel plated with phosphor bronze spring

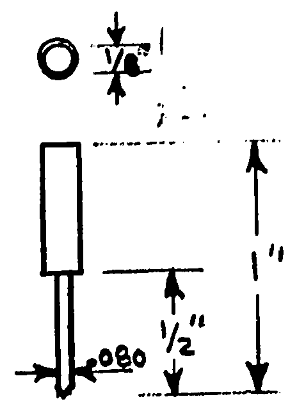


Fig. 36 Solder type phone tip brass, nickel plated

The jack and pin are modified in the following way.

a. The hex head of the jack is turned down on a lathe, a parting tool is used to cut the jack in two, and the phosphor bronze spring contact is removed (see Fig. 37).

Fig. 37. Modified jack and spring contact

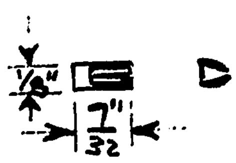


Fig. 38. Modified spring contact

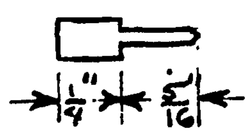


Fig. 39. Modified phone tip

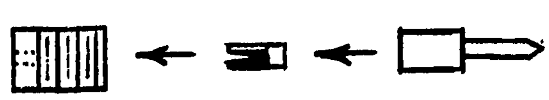


Fig. 40. Assembling the jack

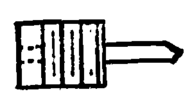


Fig. 41. The finished jack

d. The modified jack, modified spring contact, and modified phone tip are now assembled (see Fig. 40), and a small amount of solder is used to hold the assembly together.

Connectors. An assortment of connectors designed for use on the breadboard is shown in Fig. 42. The connector at the bottom has two of the jacks

1 The Radio Electronics Master, (United Catalog Publishers, Inc., 1960), page 776

Fig. 42. Assortment of connectors with jacks

described above, so that other components can be plugged in. The outside wire on the photograph is used to connect circuit elements on the bread-board to projection meters. Alligator clips are also used in many instances.

Fig. 43 shows some of the details of the connectors.

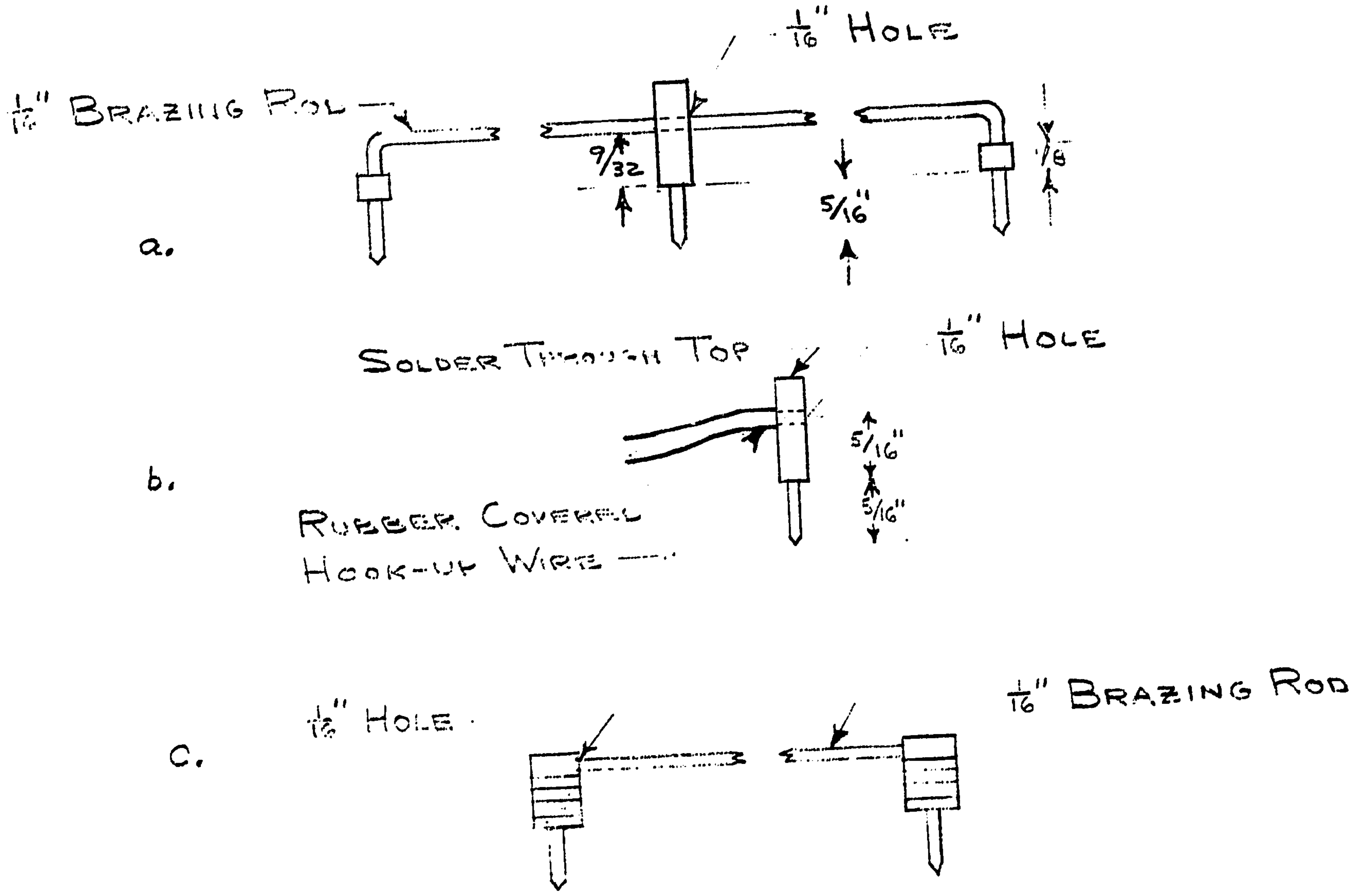


Fig. 43. Details of connectors

Electrical components. For greater flexibility, various electrical components are mounted on plastic strips. The details of a resistor

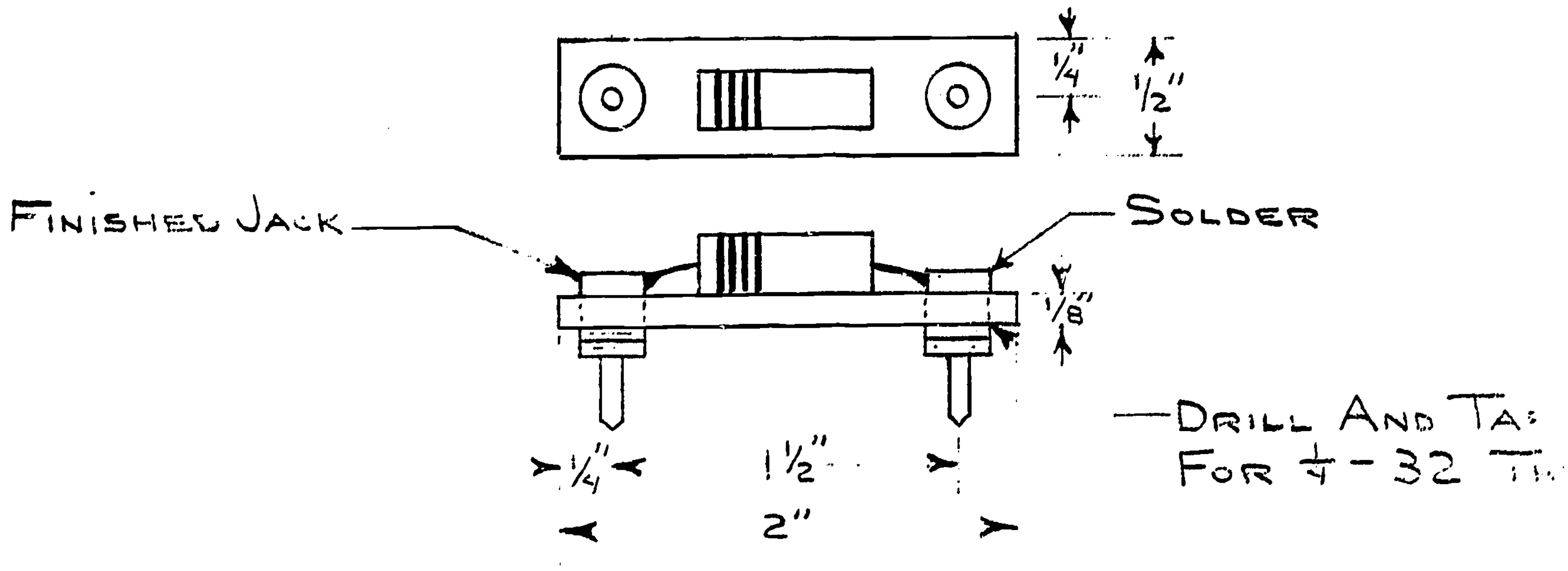


Fig. 44. Schematic of a resistor mounted on plastic strip

on a typical mount are shown in Fig. 44. Sometimes it becomes necessary to hold the component on the lucite strip by some mechanical means (scotch tape, for instance) in addition to soldering them on the jacks. The dimension of the mounting strips may vary according to the size of the electrical components used.

A large assortment of electrical components can be mounted on plastic mounting strips for use on the bread-board. In general, components should be very small for better visibility of the circuit as a whole. To give students a feeling for the size of the actual parts used, a plastic ruler is placed on the board. Among the components used are; miniature batteries, knife switches, resistors, potentiometers, rheostats, thermistors, capacitors, inductors, transformers, vacuum tube sockets, and photocells. Specially constructed parts include a slide wire potentiometer and a mount for a piece of germanium used in the demonstration of the Hall effect. A few typical electrical components on their plug-in mounting strips are shown in Fig. 45.

4. Projection meters

For the measurement of currents and voltages of more than a few milliamperes and a few volts respectively, commercially available projection meters with appropriate shunts and series resistors are used.[1,2] Because

1 Cenco No. 82550 Projection meter with No. 82552 AC-DC voltage multipliers, No. 82554 DC current shunts and No. 82556 AC current transformer, Central Scientific Company

2 Model 525, type 12 Projection instrument with No. 9664 range selector Weston Instruments

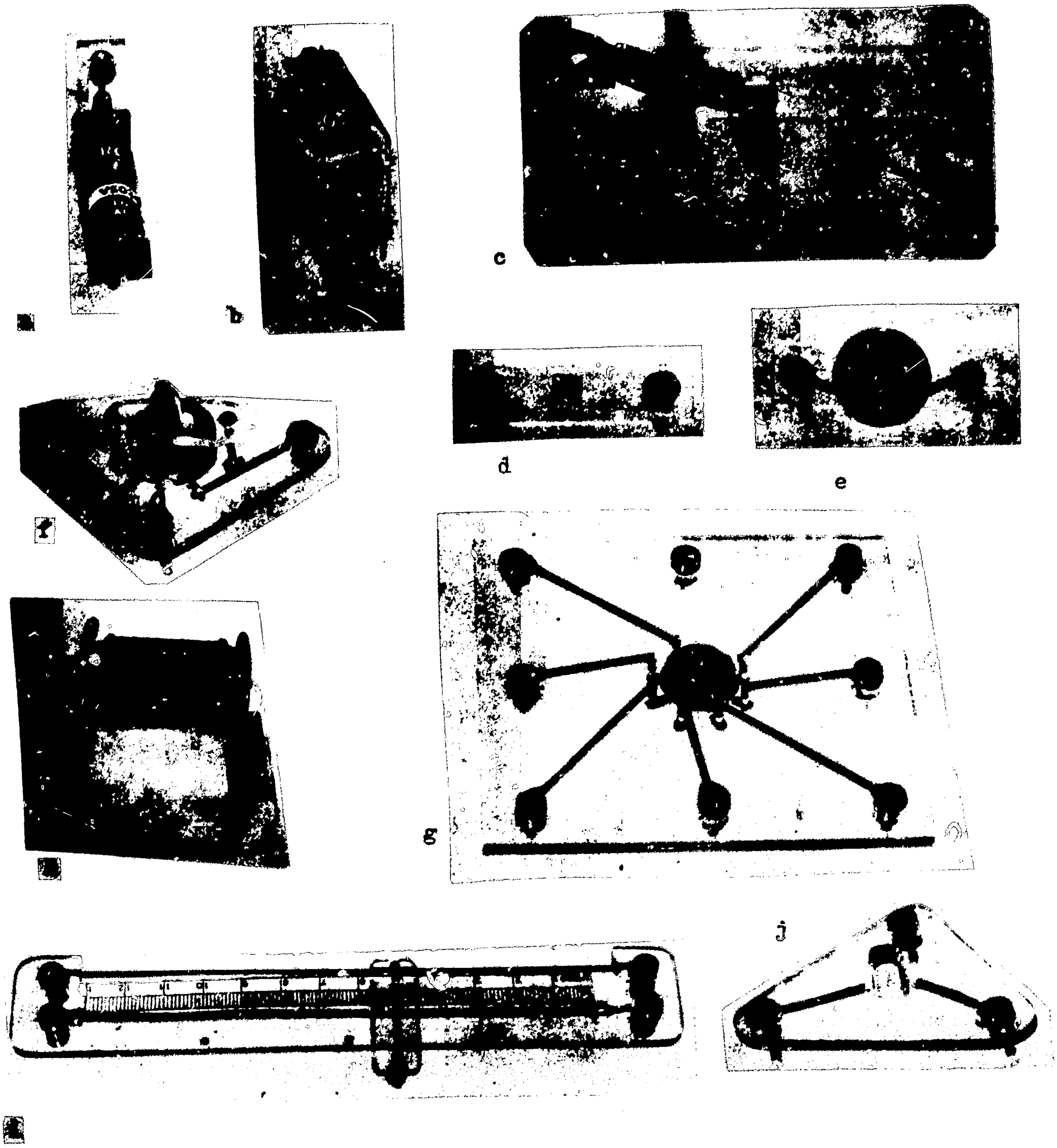


Fig. 45. Electrical components on mounting strips

a. 1 1/2 volt battery
b. 30 volt miniature battery
c. Single pole double throw switch
d. Thermistor
e. 10,000 ohm rheostat
f. 2500 ohm potentiometer
g. Socket for radio tubes, such as the 117Z3 diode or 6AB4 triode
h. 921 photocell
i. Slide wire for slide wire potentiometer
j. Mounted PNP transistor

suitable commercial projection galvanometers could not be found, the movements of regular galvanometers[1] were removed from their cases and mounted on lucite strips with jacks for plugging into the transparent bread-board. Such a galvanometer, used in a Wheatstone Bridge circuit, is shown in Fig. 50. The scale of the original meter was photographed onto a transparent film and mounted on the meter. In this manner any available meter can be used as a projection meter.

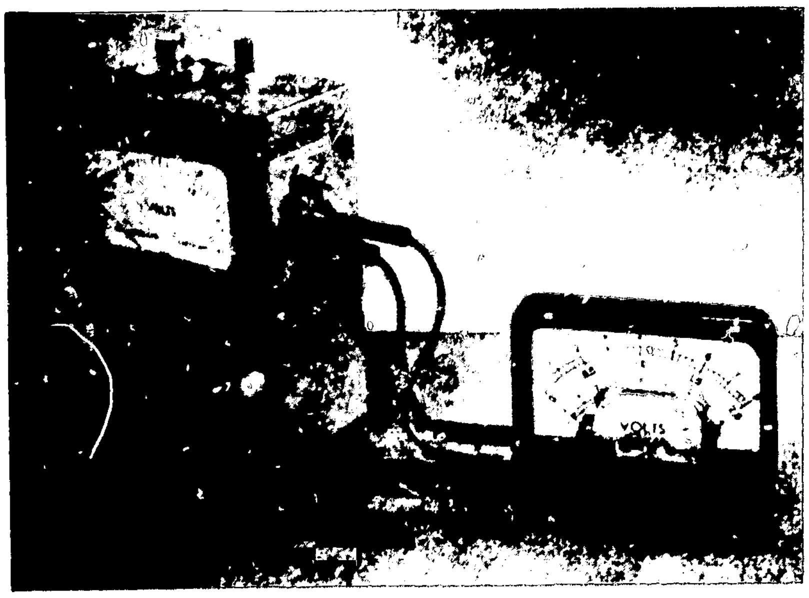


Fig. 46. Projection unit connected to Keithley electrometer

One of the most versatile meters used is the Keithley electrometer[2]. An extra meter movement for the electrometer was purchased[3]. Part of the case was carefully cut out and the meter was then mounted in a clear plastic case with a transparent photograph of the original scale as shown in Figs. 46 and 47. This projection unit can be connected to any series 200 Keithley electrometer by two removable leads.

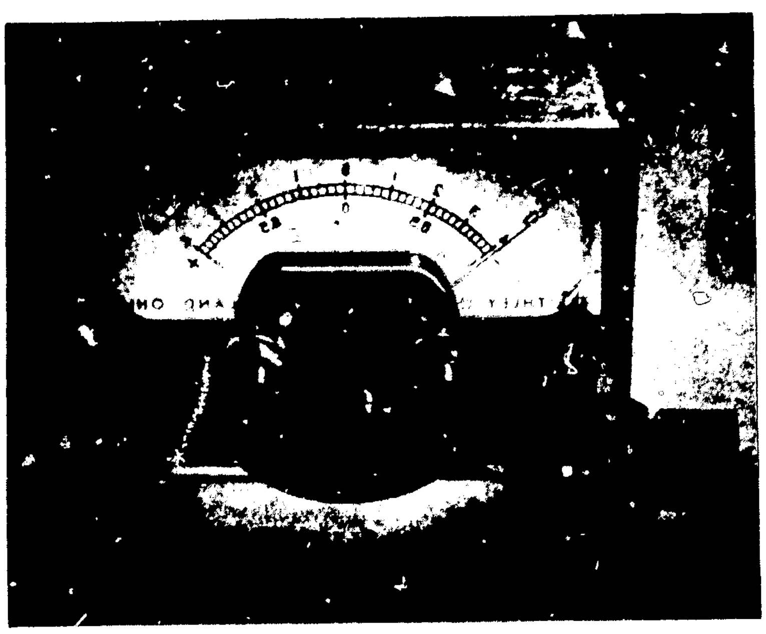


Fig. 47. Rear view of Keithley projection unit in plastic case

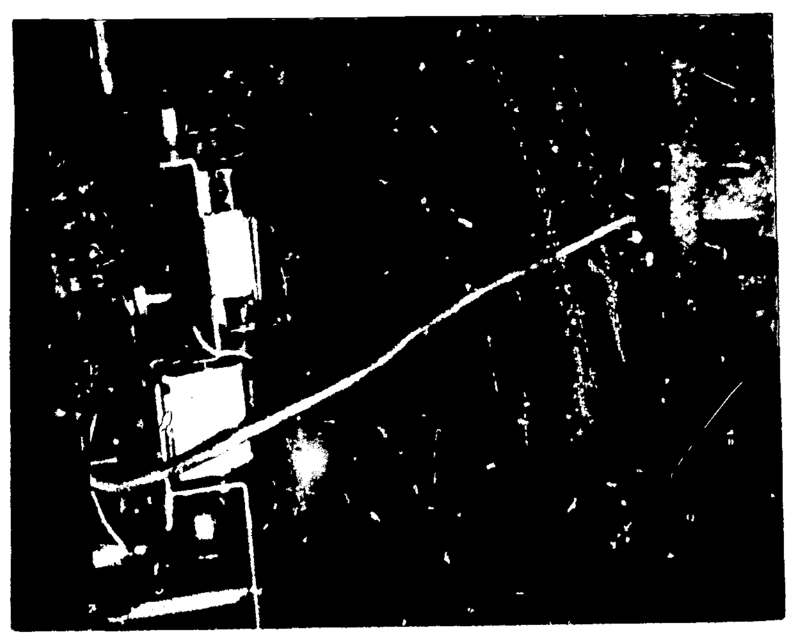


Fig. 48. Position of switch and terminals on Keithley electrometer (with electrometer case open)

1 Such as model 440 or 699, Weston instruments or their equivalent

2 Models 200 B and 200, Keithley Instruments, Inc. have been used

3 MB5, Keithley Instruments, Inc. or model 29 0-50 DC microamperes, Simpson Electric Company

A double pole double throw switch is mounted on the side of the instrument so that the electrometer can be used with either scale, the one on the meter proper or the one on the external projection unit. Details of changes made on the Keithley meter are shown in Figs. 48 and 49.

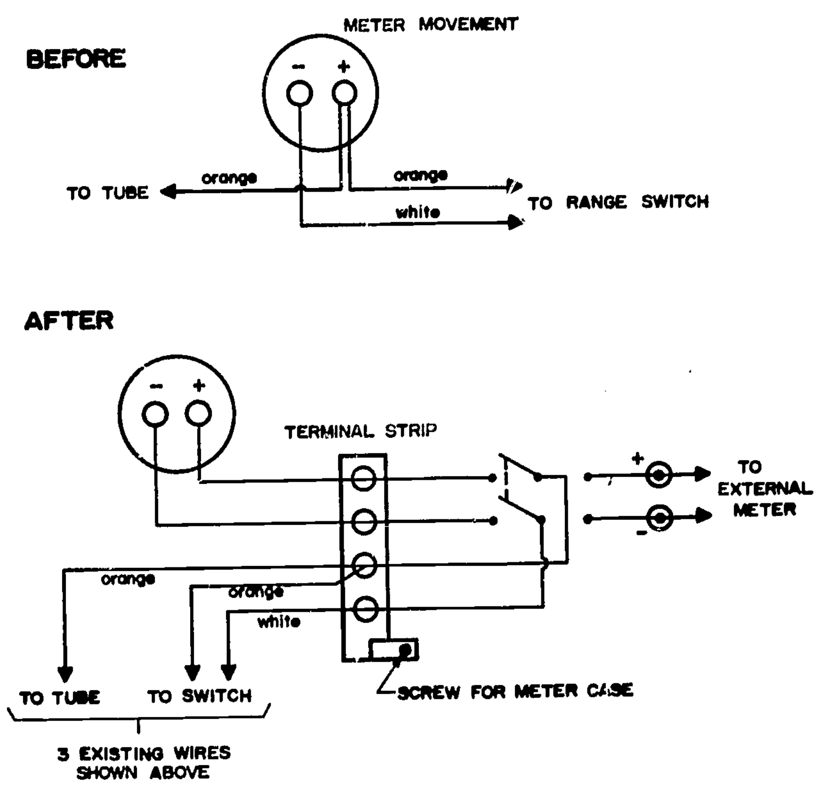


Fig. 49. Schematic for adding switch and terminals to Keithley meter

Any accessory for the Keithley electrometers can, of course, also be used with the projection unit. The decade shunt converts the electrometer into a micro-microammeter with ranges from 10^{-3} to 10^{-12} amperes.[1] Voltage dividers extend the range of the electrometer to 200, 2,000 or 20,000 volts[2] and a physics static detector[3] proves very useful in electrostatic experiments.

The Keithley projection unit has been used directly, without the electrometer, in cases where small currents of the proper magnitude had to be measured. An example is its use as a detector for 12-cm microwaves employed in many demonstrations. Direct leads from the Cenco microwave receiver[4] to the Keithley projection unit enables the lecturer to project the meter output and make quantitative measurements in front of a large group.

5. Examples of Circuits

The components previously discussed have been used on the plastic breadboard in the following circuits:

resistors in series and parallel
thermistors in circuits
Wheatstone bridge
slide wire potentiometer

1 Model 2008 (decade shunt, Keithley Instruments, Inc.)

2 Model 2003 for 200 volts, model 2006 for 2000 volts and model 2007 for 20000 volts, Keithley Instruments, Inc.

3 Model 2005 static detector, Keithley Instruments, Inc.

4 No. 80422 Microwave optics equipment, Central Scientific Company

charge and discharge of capacitor
A. C. series or parallel circuits
characteristics of diodes, triodes and transistors
photoelectric effect
Hall effect

In the case of the Hall effect demonstration, a separate plastic base was used directly on the stage of the projector because of the weight of the magnet involved. The components used, however, were of the plug-in type previously described.

Two typical circuits using the bread-board and the Hall effect demonstration are shown in Figs. 50, 51 and 52.

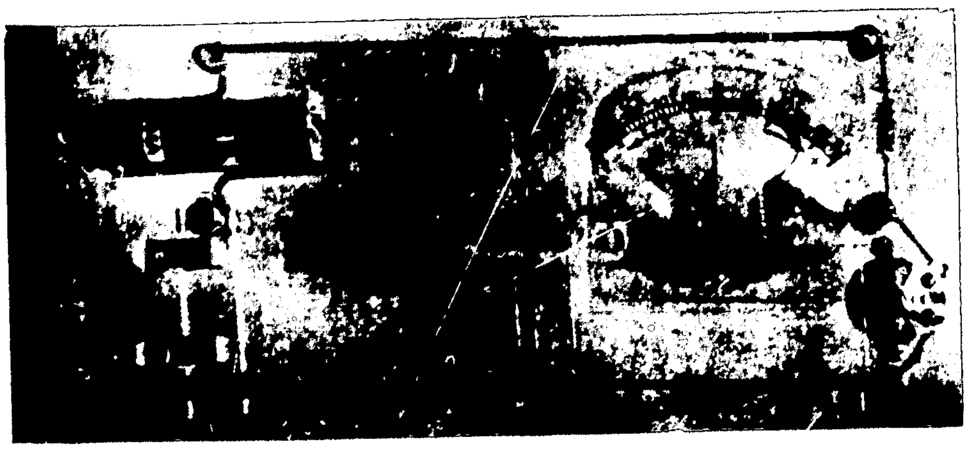
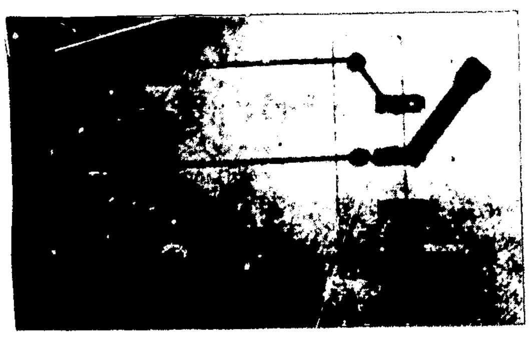


Fig. 50. Wheatstone bridge consisting of a 1 1/2 volt battery, a miniature knife switch mounted sideways on a plastic strip, three 1000 ohm resistors, a 2500 ohm rheostat and a galvanometer on a plastic plug-in mount.



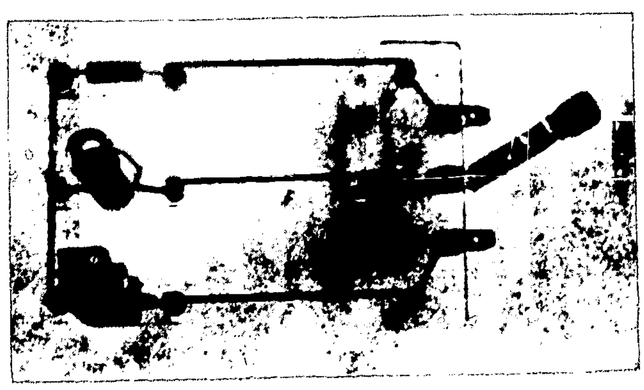


Fig. 51. Charge and discharge of a capacitor

a. A 30 volt battery, a 1 μf capacitor, a 7 megohm resistor and a single pole double throw switch mounted on a plastic bread-board. A Keithley electrometer, not shown, is used to measure the potential difference across the capacitor.

b. The circuit in shadow projection as it appears on the screen. Symbols are written directly on the plastic bread-board or on the circuit diagram projected first. Alligator clips are used to connect the electrometer.

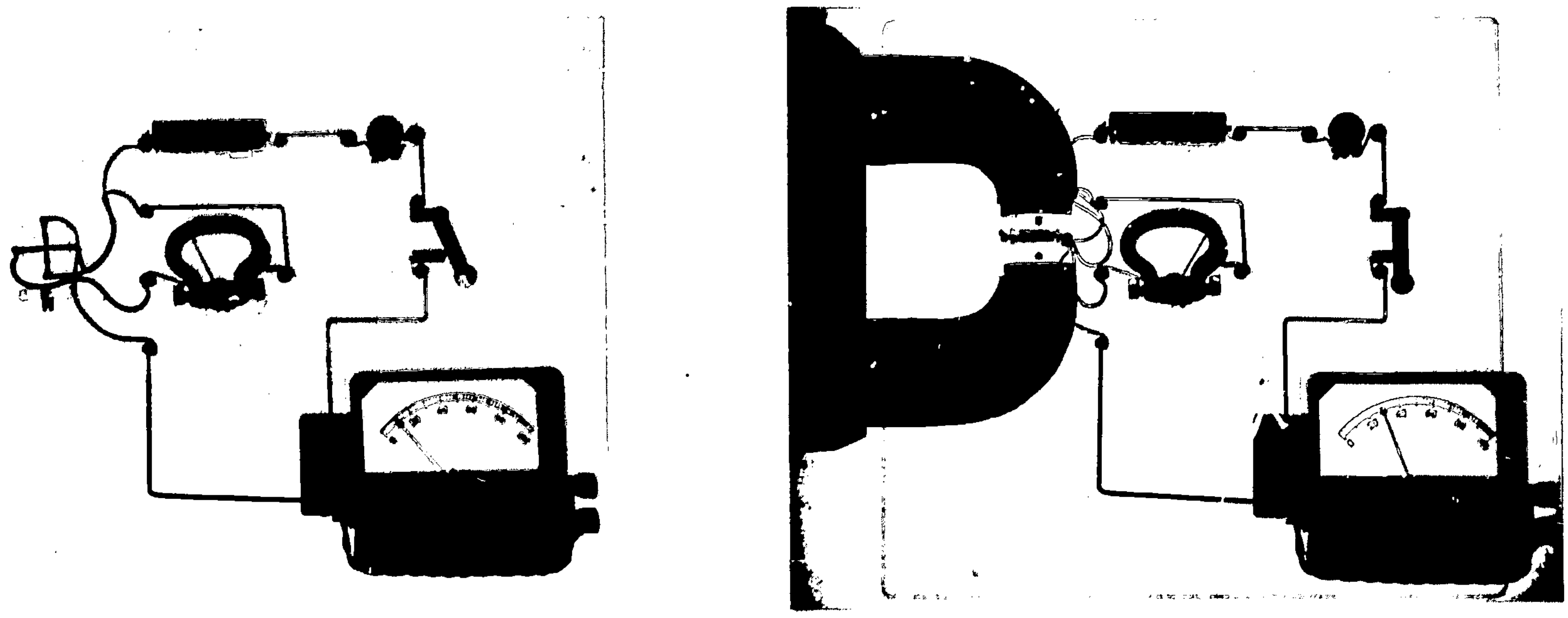


Fig. 52. Hall effect demonstration

a. 30 volt battery, 2500 ohm rheostat, knife switch, projection meter with 100 milliampere shunt, in series with germanium sample shown in projection. A projection galvanometer is connected across germanium strip.

b. Germanium sample mount is plugged into base and a magnetron magnet is placed across it to detect Hall voltage.

PART IV

AN X-Y PLOTTER FOR THE OVERHEAD PROJECTOR

1. Purpose of the Plotter

In physics it is highly desirable to show functional relationships between measurable quantities. An effortless procedure would be for the lecturer to present the students with a graph, shown on the overhead projector or by any other means. This does not answer the question, however, how these plots are actually obtained, nor does it give the student a feeling for the experimental method of plotting variables first and then trying to deduce the mathematical relationships. For this purpose, in many of our research laboratory X-Y plotters or recorders are in use.

When we deal with a repetitive phenomenon, we could use an oscilloscope to show such relationships. The relation between B and H for an iron ring, resulting in a hysterisis curve, can be shown easily on an oscilloscope. The convenience of using a frequency of 60 cycles per second is obvious. When we want to demonstrate the relation between charge and time of a charging or discharging capacitor, however, we do not deal with a repetitive process, and an X-Y plotter is called for.

A commercially available recorder is not suitable for lecture demonstrations given to large groups, because of the difficulty in making the trace visible and the rather high cost of such devices. For this reason it was decided that an X-Y plotter should be constructed to fit on the stage of an overhead projector thereby making the traces visible to large audiences. Since the plotter would not be used for detailed quantitative data, but only for qualitative demonstrations, it does not require the accuracy most commercial recorders have. This, of course, would decrease the cost appreciable.

2. Description

With the purposes stated above in mind, such an X-Y plotter for overhead projectors was designed and built at Rensselaer Polytechnic Institute and is shown in Fig. 53.[1] Besides the plotting table shown, an additional unit, consisting of a power supply and an amplifier, is required and is shown in Fig. 54.

1 The R. P. I. X-Y plotter was designed by George F. Robinson of the Department of Physics. This project was partially supported by the General Electric Educational and Charitable Trust.

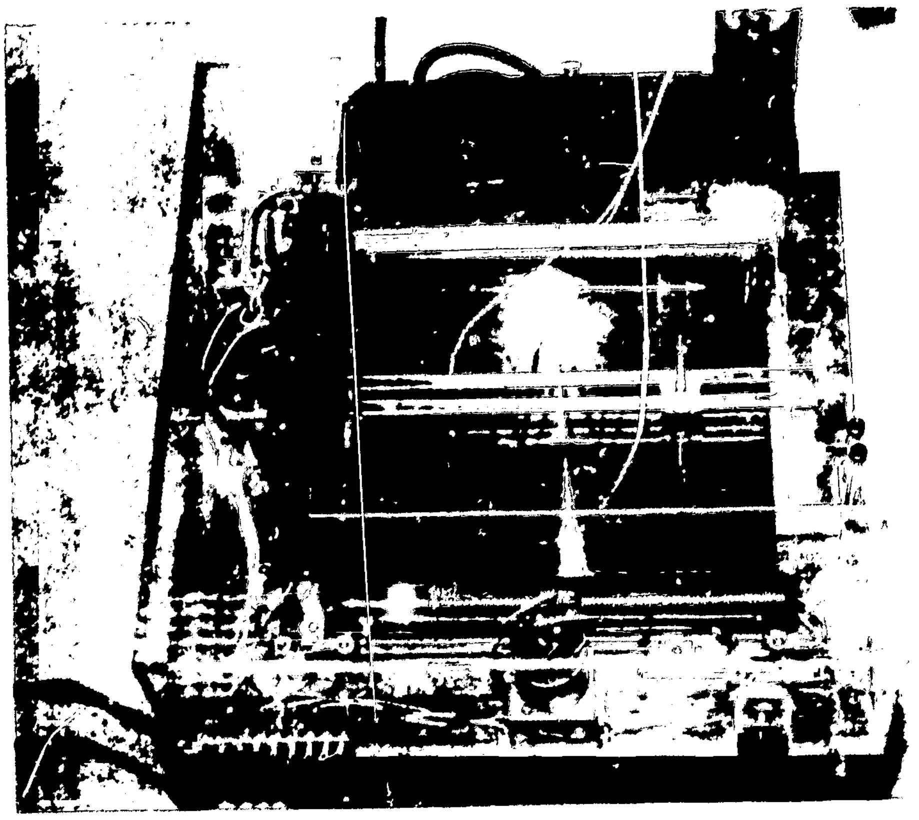


Fig. 53. The X-Y plotter on the stage of an overhead projector

In the operation of the plotter, a potential is applied to either the X or Y inputs and is nulled out by the action of the servo amplifier-motor-potentiometer combination. This results in a point on the potentiometer slider taking on the negative of the applied potential. Since the slider is mechanically connected to the plotting arm the arm will follow the applied potential. X and Y channels are identical in all respects.

Provision is made for setting the initial position of both plotting arms to any desired location in the plotting area.

The plotting pen is carried in a bushing at the intersection of the plotting arms and writes directly on the transparent material used with the projector. Three pens, containing different colored inks, are held in readiness by a holder mounted on the plotting table.

The sensitivity is approximately 18 volts/inch and 180 volts are required to produce full scale deflection. Best results are obtained if all important frequency components in the input signal are less than 1/2 cycle/sec.

The details of this apparatus, including all circuit diagrams, construction notes and materials lists are given in the Apparatus Drawings Project Report Number 28 by Robert G. Marcley.[1]

3. Applications of the X-Y Plotter

Just as any lecturer will find many interesting uses for overhead projectors, he will also find numerous applications of the X-Y plotter. A list of demonstrations successfully performed with this plotter as well as suggestions for other uses is given in the report of the NSF-RPI 1960 Summer

1 Am. J. Phys. 30, in press (1962)

Workshop [1] Demonstrations successfully performed in our introductory physics course include the following:

Charge and discharge of a capacitor. For this and other applications an auxiliary amplifier and horizontal sweep circuit is necessary for a time base along the x-axis. With this unit, the circuit shown in Fig. 51 can be used to show the discharge of a capacitor. The voltage across the resistor is proportional to the current in the circuit, while the potential across the capacitor is proportional to the charge.

Bragg diffraction. The Bragg diffraction model using 3-cm microwaves developed by Professor Harry F. Meiners of Rensselaer Polytechnic Institute and described in the Apparatus Drawings Project Report Number 6 by Robert G. Marcley[2] can be coupled to the X-Y plotter.[3] This combination enables the student to see an intensity curve develop on the screen as the angle of incident radiation is changed. A D. C. voltage proportional to the angular displacement between radiation source and detector is used to drive the X-arm of the plotter. The Y-arm is driven by the amplified and rectified output of a standing wave indicator.

Analog computer. A portable analog computer[4] with its output fed into

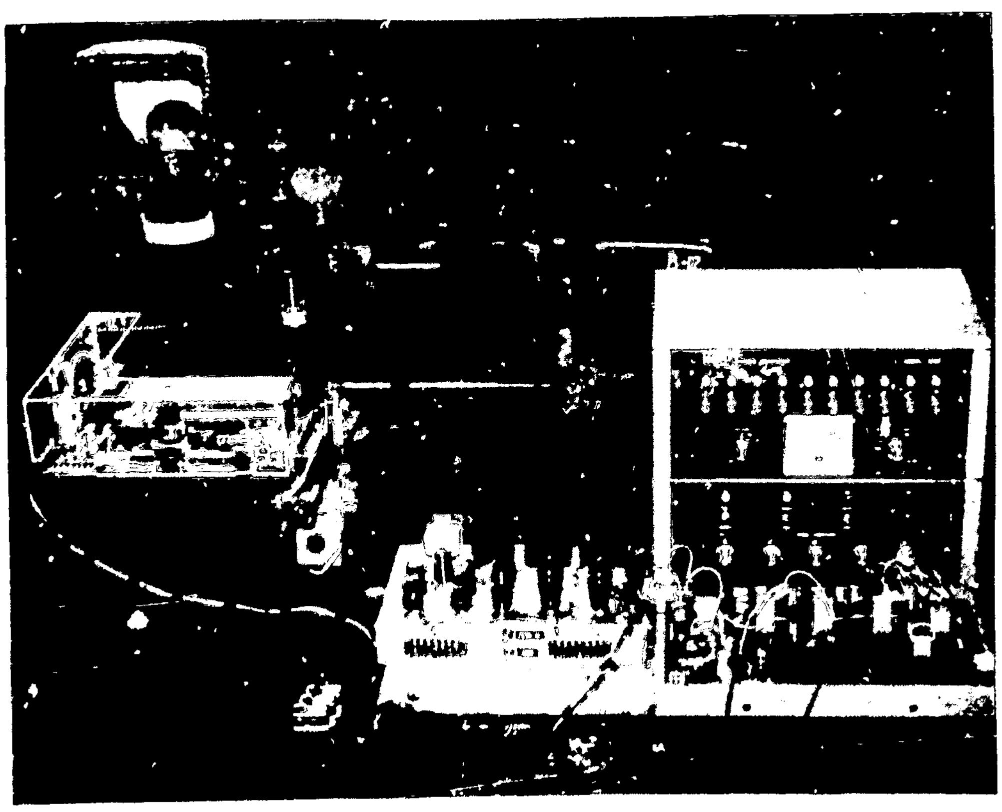


Fig. 54. An analog computer (right) connected to the power supply and amplifier (center) for the X-Y plotter on an overhead projector (left)

1 Demonstration and Laboratory Apparatus Report of the 1960 Summer Visiting Professor Workshop, Rensselaer Polytechnic Institute, Troy, N. Y., 1961 pages 162-176

2 Am. J. Phys. 415, 28 (1959)

3 Harry F. Meiners, Am. J. Phys. 680, 27 (1959)

4 Model 3000, Donner Scientific Company has been used

the X-Y plotter is a very valuable addition to many demonstration lectures. It can be used to plot functional relationships not easily available from other apparatus. It may also be put to use to exhibit solutions of differential equations. Some of these the students might solve themselves, however others might be too complicated for Freshman or Sophomores. Two examples of the use of such a computer in elementary physics involve projectile motion and forced oscillations, either mechanical or electrical.

The differential equation for the path of a projectile may be set-up on the computer for a certain initial velocity, angle, acceleration of gravity and air resistance. The output of the computer is fed into the X-Y plotter and students see the actual projectile path on the screen. We can then change any of the variables, such as air resistance or acceleration of gravity, and plot the resultant path in a different color.

The same plots apply, of course, to any projectile motion, such as may be experienced by an electron in an electric field.

When discussing forced oscillations, the analog computer can be used to plot the displacement or velocity as a function of time for various frequencies. It is instructive to plot three such curves - in different colors on the same coordinates - for a driving frequency below resonance, at resonance and above resonance.

The same set-up can be used, of course, for the forced oscillations of an LCR circuit resulting in plots for charge and current as a function of time and illustrating phase relationships between the various plots. The transient term can be illustrated as well as the steady state solution.

APPENDIX A

BIBLIOGRAPHY

The large number of articles in educational audio-visual and business journals are not included because most of these do not deal with the use of overhead projection techniques as applied to college level physics courses.

1. Pamphlets Published by Manufacturers of Projection Equipment

Diazochrome Slides for Visual Communication, Tecnifax Corporation, Holyoke, Mass.

Making Black-and-White Transparencies for Overhead Projection, Kodak Pamphlet No. S-7, Eastman Kodak Company, Rochester 4, N. Y.

Overhead Projection by Horace C. Hartsell and W. L. Veenendaal, Henry Stewart, Inc. Publishers, Buffalo, N. Y., 1960 (American Optical Company)

They See What You Mean, Visual Communication with the Overhead Projector, Ozalid Audio-Visual Department, Ozalid, Division of General Aniline and Film Corporation, Johnson City, New York, 1959

Visucom Equipment and Materials, published by Tecnifax Corporation, Holyoke, Mass.

Vu-Graphics, Charles Beseler Company, East Orange, N. J.

2. Recent Reports on the Use of Overhead Projectors

Applications of the Overhead Projector to the Teaching of Chemistry Rev. Laurence J. McGowan, Archbishop Stepinac High School, White Plains, N. Y.

Design and Development of Transparent Over-lay Visual Aids for Teaching Basic Principles of Engineering Graphics, Report on NSF Grant G9291, H. M. Neely, Kansas State University, Manhattan, Kansas

Experimentation in the Adaptation of the Overhead Projector in Teaching Engineering Descriptive Geometry Curricula, Report on grant 741023.09, U. S. Office of Education, Department of Health, Education and Welfare, Clayton W. Chase, University of Texas

Tested Overhead Projection Series (TOPS), Hubert N. Alyea, Department of Chemistry, Princeton University, to be published in J. Chem. Edu., January 1962 and THE SCIENCE TEACHER, February 1962

3. Recent References to Overhead Projection in Physics

Demonstration and Laboratory Apparatus Report of the 1960 Summer Visiting Professor Workshop, Rensselaer Polytechnic Institute, Troy, N. Y., 1961

Modern Physics Buildings, R. Ronald Palmer and William Maxwell Rice, Reinhold Publishing Corporation, New York, 1961, page 158

More Visual Aids in the Physics Lecture, Am. J. Phys. 29, 134 (A) (1961)

Use of an Overhead Projector in Demonstrations before Large Groups, Am. J. Phys. 27, 443 (A) (1959)

APPENDIX B

SOURCES OF EQUIPMENT AND MATERIALS

1. Purchasing an Overhead Projector

Fundamentally there seems to be no great difference between the various models of overhead projectors now on the market. Most 10" x 10" models have 1000 watt lamps, type T-20, medium pre-focus (MPF). The most common lens is 14" F/3.5 (4" diameter). Most, but not all manufacturers use Fresnel lenses between the light source and the stage. Recent makes include 110 volt outlets to plug in various accessories.

The reflection of light into the eyes of the lecturer as well as the noise of the cooling fan may prove annoying in some cases. There has been a trend to lower projection heads in order to avoid obstructions. These projectors are designed, of course, for transparencies and overlays and not necessarily for models and demonstration equipment. For this reason some types will not focus on planes more than 1 or 2 inches above the stage. When the projector has a very low head, it may also be difficult to perform an experiment on the stage of the projector. Manufacturers should always be consulted for all details, especially those not listed in their literature.

The author did not have the opportunity to actually test all projectors mentioned. Most of the demonstrations described in this report were carried out on the Beseler Master Vu Graph. For the projection of overlays the Thermo-Fax, Ozalid and Transpaque models were also used.

The table on page 53 lists specifications and prices for eleven overhead projectors and six of these are illustrated in Fig. 55.[1] This is no implication that the list includes all projectors available. Models are listed alphabetically by company name, then in ascending order by list price. Only models with a 10" x 10" stage have been included in the table. Every effort has been made to gather accurate information, but the possibilities of errors always exists. All prices are always subject to change without notice by the manufacturers.

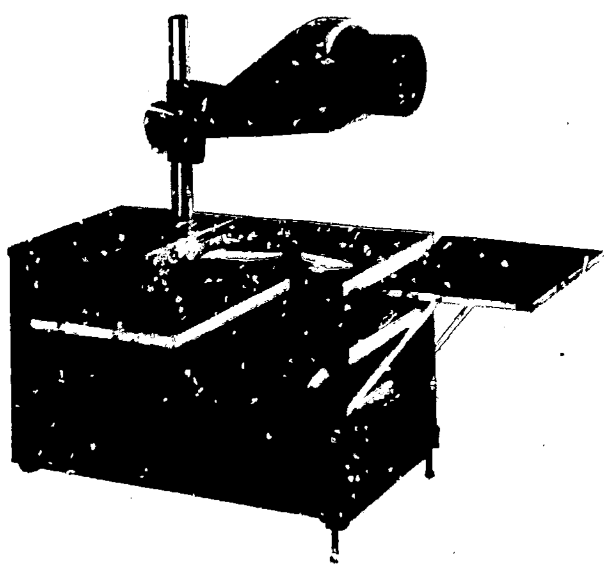
1 Information on most available models is given in THE AUDIO-VISUAL EQUIPMENT DIRECTORY, published by the National Audio-Visual Association, Inc., 1201 Spring Street, Fairfax, Virginia, Seventh edition ($4.75), pages 59-66

Specifications and prices of some 10" x 10" overhead projectors

Company	Model	Lamp	Lens	Weight	Price	Remarks
American Optical Comp. Instrument Division, Buffalo 15, N. Y.	#3350 Overhead Delineascope	1000 watts	14" F/3.5	36 lbs.	$315.-	Built-in roll attachment, folding shelf in front
	#3540 Overhead Delineascope	1000 watts	14" F/3.5	32 lbs.	$395.-	Front and side shelf - lower head than #3350
Charles Beseler Company, 219 South 18th St. East Orange, N. J.	#6600 Master Vu-Graph[1]	1000 watts	14" F/3.5	34 lbs.	$315.-	Built-in roll, support shelf
	#7750 Vu-Graph	1000 watts	14" F/3.5	34 lbs.	$345.-	Built-in roll, support shelf.
	Vu-Graph Royal	1000 watts	10 lenses available, ranging from 8.8" to 40" with a price range from $495.- (14" lens) to $815.- (40"lens)			
Minnesota Mining and Manufacturing Comp. St. Paul 6, Minn.	Thermo-Fax Portable	500 watts	14" F/3.5	30 lbs.	$329.-	Portable
	Thermo-Fax	1000 watts	14" F/3.5	38 lbs.	$395.-	
Ozalid Division General Aniline and Film Corp. Johnson City, N. Y.	#252-100 Projecto-Lite	750 watts	14" F/3.5	49 lbs.	$495.-	Rotating head
Projection Optics Comp., Inc. 271 11th Ave. East Orange, N. J.	#6000A Transpaque[2]	1000 watts	14" F/3.5	36 lbs.	$395.-	Ellipsoidal reflection system
	#6009 Transpaque[2]	1000 watts	14" F/3.5	36 lbs.	$425.-	6000A and 6009 are the same except for lower head on 6000A
	Transpaque II[2]	1000 watts	10" lens 14" lens 40" lens		$699.- $574.- $1036.-	convertible to opaque projector for additional cost of $255.- to $282.-
Victorlite Industries, Inc., 4177 W. Jefferson Blvd. Los Angeles, Calif.	#3000 Visual Cast Instructor	500 watts	14"	40 lbs.	$294.-	

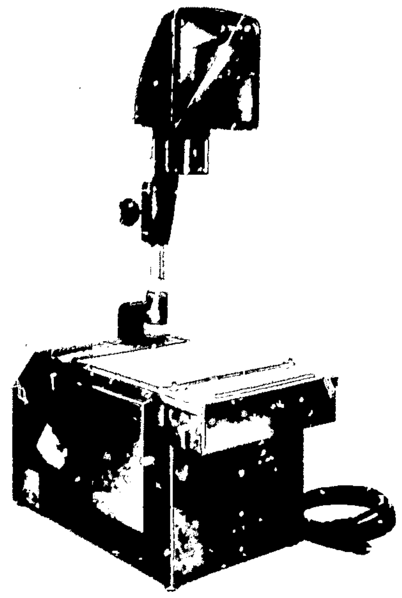
1 The W. M. Welch Scientific Company sells the #6600 Master Vu Graph (No. 3978) as well as many of its accessories (No. 3978A through 3978V)

2 Transpaque projectors are sold by the Tecnifax Corporation and their distributors

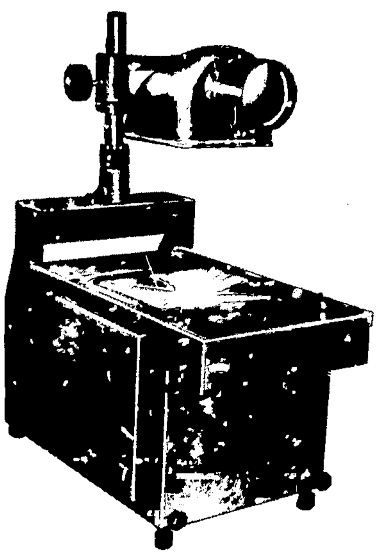


American Optical Overhead
Delineascope

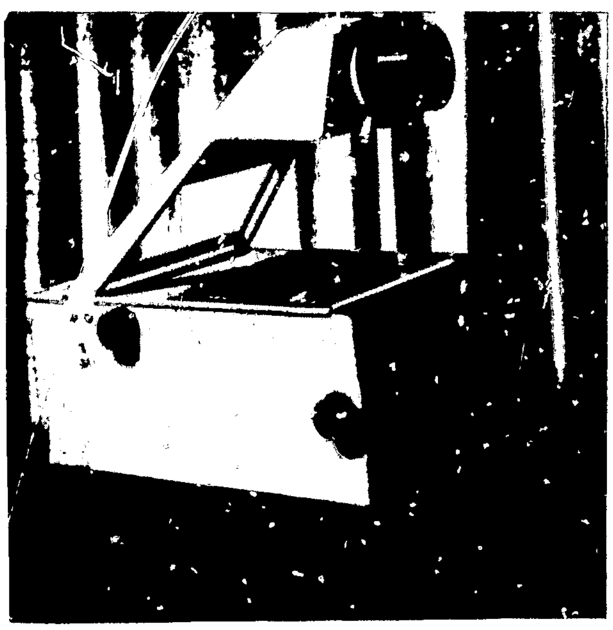
Ozalid Projecto-Lite
Overhead Projector



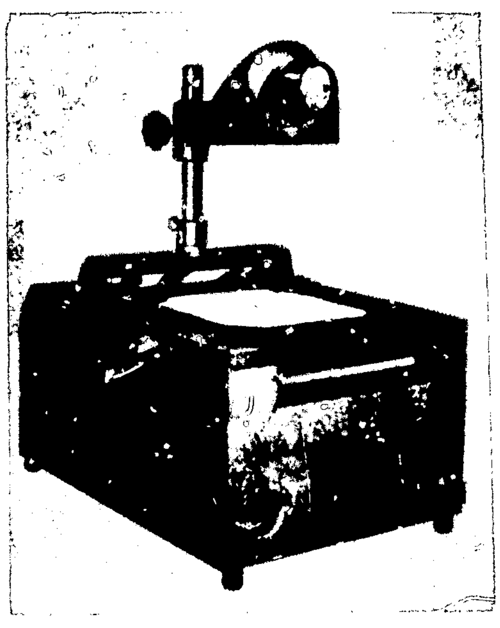
Beseler Master Vu-Graph



Beseler Vu-Graph 7750



Thermo-Fax Projector



Transpaque Projector

Fig. 55. Overhead Projectors

Among overhead projectors with stages other than 10" x 10" the following models are available:

Act-O-Matic Projector, distributed by Tecnifax Corp. Can be used for horizontal and vertical projection	5" x 5" stage	$ 396.-
Bausch and Lomb Balopticon	3 1/4" x 4" stage	$ 190.-
Beseler Vu-Graph 55	5" x 5" stage	$ 155.-
Beseler Jr. Vu-Graph	7" x 7" stage	$ 215.-
Beseler X-Ray Vu-Graph	13" x 16" stage	$2995.-
Keystone View Projector	2 7/8" x 3 3/8"	$ 225.-
E. Leitz Prado 250/500	2" x 2" stage - many accessories for teaching physics available from E. Leybold, Cologne, Germany	
E. Leitz Diascriptor	12 1/2" x 12 1/2"	$5379.-
Victorlite #2000	9" diameter	$ 265.-
Victorlite #1100	7" x 9"	$ 270.-
Victorlite #5200	4" x 5"	$ 402.-

2. Overhead Projector Accessories

Some of the accessories available from the manufacturers listed on page 53 include the following items:

carrying case, support shelves, dust cover stands and tilting tables of different heights, with and without casters, heat absorbing filter, cellophane and acetate rolls, plastic sheets, with and without grids, various colors, marking pencils, colored inks, mounts, polarizing spinner, transparent slide rule, foot switches, slide attachments, transparency pin locator.

3. Materials for Producing Transparencies

A wide variety of materials for the production of transparencies are available. Among the many companies, carrying art supplies, transparent tapes, diazo and photographic materials, printing machines, etc. are the following:[1]

1 Additional companies are listed in A V Materials Handbook, Indiana University Audio-Visual Center, Bloomington, Indiana, 2nd edition, 1960 ($2.00)

Applied Graphics Corporation
Glenwood Landing, N. Y.

Arthur Brown and Bro., Inc.
2 West 46th Street
New York 36, N. Y.

Charles Beseler Company
219 South 18th Street
East Orange, N. J.

Charles Bruning Company
1800 W. Central
Mount Prospect, Illinois

Chart-Pak, Inc.
Leeds, Massachusetts

Copycat Corporation
41 Union Square West
New York, N. Y.

Eastman-Kodak Company
Rochester 4, N. Y.

Jay G. Lissner, Artist Aid Patterns
3417 W. 1st Street
Los Angeles 4, Calif.

Mico/Type Inc.
6551 Sunset Blvd.
Los Angeles 28, Calif.

Ozalid Division
General Aniline and Film Corp.
Johnson City, N. Y.

Pelprinter, Inc.
555 Central Avenue
Orange, N. J.

Technical Animations Incorporated
11 Sintsink Drive E., P. O. Box 632
Port Washington, N. Y.

Tecnifax Corporation
Holyoke, Massachusetts

APPENDIX C

TITLES OF COLORED OVERLAYS PRODUCED

Among the transparencies produced for teaching introductory physics to Freshman and Sophomores at Rensselaer Polytechnic Institute, there is a series of 66 overlays consisting of 240 visuals prepared by a professional artist. These transparencies were designed for use in lecture halls seating 250 or more students. It is hoped that this series can be extended in the future and it is planned to make these overlays commercially available.

The titles listed below do not include transparencies specifically designed for use with the bread-board circuits discussed in parts III of this report. Topics preceded by a T have a technamated transparency, but can also be used without a polarizing spinner.

Resolution of vectors
Projectile motion
Circular motion
Work, force and distance
Potential surfaces
Collisions
Springs
Damped harmonic motion
Kepler's law of equal areas
Superposition of six sine waves
Standing waves - 3 harmonics
Circular standing waves (De Broglie)
T Wavelengths in different media
P-V diagram for Carnot cycle
P-T plots for ideal and real gas
P-V-T diagram
Molecular speed distribution apparatus
Molecular speed distributions
Electrostatic fields due to two equal charges
Dialectrics
Polarizability of spherical atom
Dialectric and conducting sphere in an electric field

Electric intensity and displacement across boundary
Electron drift
Cathode ray tube
Ammeter and voltmeter
T Kirchhoff's rules
Force on moving charge in magnetic field
Mass spectrometer
Cyclotron
Electromagnetic velocity selector
Biot's law
Magnetic field due to long wire
Magnetic field due to circular loop
Solenoid
Magnetic field of solenoid
Primary and secondary coils
Wire in magnetic field
Rowland ring
Hysteresis loop
A. C. series circuit
L. C. circuit
Oscillating electric dipole

Electromagnetic waves

Electromagnetic waves

Electromagnetic spectrum

Prism

T Optical instruments - overhead projector

T Optical instruments - projector

T Optical instruments - microscope

T Optical instruments - telescopes

The eye

T Wave through aperture

2 slit interference

2 and 4 slit diffraction patterns

Thin film interference

Fizeau measurement of speed of light

Michelson interferometer

X-Y-Z coordinates for 2 frames of reference

Relativity

Bohr atom

Balmar series

Energy levels for sodium

Crystal planes

Uranium series

Bubble chamber tracks